LEVIATHAN MINE NATURAL RESOURCE DAMAGE ASSESSMENT PLAN

PUBLIC RELEASE DRAFT

Prepared by:

The Leviathan Mine Council Natural Resource Trustees:

Washoe Tribe of Nevada and California
U.S. Bureau of Indian Affairs
U.S. Fish and Wildlife Service
U.S. Forest Service
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and
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May 6, 2002
SC10035

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Acronyms

ALC	aquatic life criteria
AM	Assessment Manager
AMD	acid mine drainage
AOC	Administrative Order on Consent
ARCO	Atlantic Richfield Company
BIA	Bureau of Indian Affairs
CCC	criteria continuous concentration
CCR	California Code of Regulations
CDFG	California Department of Fish & Game
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CMC	criteria maximum concentration
COC	chain of custody
CV	contingent valuation
CWA	Clean Water Act
DM	Departmental Manual
DOI	Department of the Interior
DQO	data quality objective
EPA	Environmental Protection Agency
FTL	Field Team Leader
GIS	geographic information system
IAM	Indian Affairs Manual
LMC	Leviathan Mine Council
LRWQCB	Lahontan Regional Water Quality Control Board
MCL	Maximum Contaminant Levels
MCLG	Maximum Contaminant Level Goals
MDL	method detection limit
MOA	Memorandum of Agreement
NAC	Nevada Administrative Code
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NDEP	Nevada Division of Environmental Protection
NFS	National Forest Service
NPL	National Priorities List
NRDA	natural resource damage assessment
PEC	probable effect concentration
PI	Principal Investigator
PM	Project Manager

PRPs	potentially responsible parties
PSD	Preassessment Screen Determination
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
RCDP	Restoration and Compensation Determination Plan
RCRA	Resource Conservation and Recovery Act
REA	resource equivalency analysis
RI/FS	Remedial Investigation/Feasibility Study
RPD	relative percent difference
RPM	Remedial Project Manager
SDWA	Safe Drinking Water Act
SDWR	Secondary Drinking Water Regulations
SOP	Standard Operating Procedure
SRM	standard reference material
TEC	threshold effect concentration
TSA	Technical System Audit
USFS	U.S. Department of Agriculture, Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WASP	Water Analysis Simulation Program

1. Introduction

1.1 Statement of Purpose

The Washoe Tribe of Nevada and California (Washoe Tribe), the U.S. Department of the Interior (DOI), Bureau of Indian Affairs (BIA) and U.S. Fish & Wildlife Service (USFWS); the U.S. Department of Agriculture, Forest Service (USFS); the California Department of Fish & Game (CDFG); and the Nevada Division of Environmental Protection (NDEP) (collectively, the Trustees) are intending to continue to assess damages to natural resources that have resulted from releases of hazardous substances from the Leviathan Mine (the mine) in Alpine County, California, to the Leviathan Creek, Aspen Creek, and Bryant Creek watersheds, the East Fork of the Carson River, and other areas containing potentially injured natural resources. This assessment has been initiated pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) [42 USC § 9607(f)], the Clean Water Act (CWA) [33 USC §§ 1321(f)(4)-(5)], the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) [40 CFR Part 300 Subpart G], and the DOI's natural resource damage assessment (NRDA) regulations [43 CFR Part 11]. CERCLA and the CWA hold those parties responsible for releases of hazardous substances liable for "damages for injury to, destruction of, or loss of natural resources, including the reasonable costs of assessing such injury, destruction, or loss resulting from such a release" [42 USC § 9607(a)]. Certain federal, state, and tribal governmental entities having some trust responsibility over the impacted natural resources are entitled to bring such a claim.

The purpose of this Assessment Plan is to document the Trustees' basis for conducting a damage assessment, and to organize the proposed approach for determining and quantifying natural resource injuries and calculating the damages associated with those injuries. By developing an Assessment Plan, the Trustees can ensure that the NRDA will be completed at a reasonable cost. The Trustees also intend for this plan to communicate proposed assessment methods to potentially responsible parties (PRPs) and to the public in an effective manner so that they can productively participate in the assessment process. The PRPs currently conducting response actions at the Leviathan Mine are the Atlantic Richfield Company (ARCO), whose wholly owned subsidiary, Anaconda Copper Mining Company, formerly owned and operated the mine, and the State of California, as the current owner of the mine property through the Lahontan Regional Water Quality Control Board (LRWQCB), which has operated a pollution abatement project at the mine since 1983.

This Assessment Plan is divided into six chapters. Chapter 1 introduces the plan by describing the authority and process by which the Trustees have undertaken the development of the assessment. Chapter 2 discusses the geography of the assessment area, the history of the mine, the nature of the releases, the natural resources involved, and the time period for natural recovery of natural resources. Chapter 3 confirms that some of the natural resources in question have been exposed to hazardous substances released from the mine. In Chapter 4, the approaches for assessing injuries to different natural resources are presented. Chapter 5 addresses the method for quantification of injuries to natural resources in terms of lost services provided to the Washoe Tribe. Chapter 6 then discusses how the Trustees plan to approach the development of a Restoration and Compensation Determination Plan (RCDP) for purposes of determining damages. Appendix A gives a detailed description of resource equivalency analysis, which will be used to value the reductions in natural resources. Appendix B provides the Quality Assurance Project Plan.

1.2 Legal Authority of Trusteeship

1.2.1 Washoe Tribe

An Indian tribe may be a trustee for "natural resources belonging to, managed by, controlled by, or appertaining to such tribe, or held in trust for the benefit of such tribe, or belonging to a member of such tribe if such resources are subject to a trust restriction on alienation . . ." [42 USC § 9607(f)(1)]. Such natural resources include "their supporting ecosystems" [40 CFR § 300.610]. The NCP recognizes the Chairman of an Indian tribe as a natural resource trustee acting on behalf of the tribe [40 CFR § 300.610].

The chairman of the Washoe Tribe asserts trusteeship for all natural resources within the Washoe Indian community of Dresslerville, held in trust for the Washoe Tribe by the United States; within the Public Domain Allotments; and within the Tribe's aboriginal territory, including Leviathan Creek, Bryant Creek, and the East Fork of the Carson River.

1.2.2 Federal Trustees

As directed to under CERCLA [42 USC § 9607(f)(2)(A)], the President has designated in the NCP the federal officials who are authorized to serve as natural resource trustees [40 CFR § 300.600(b)].

The Secretary of the Interior has trustee authority under the NCP for natural resources "belonging to, managed by, held in trust by, appertaining to, or otherwise controlled" by the DOI. Such natural resources include "land, fish, wildlife, biota, air, water, ground water, drinking water supplies, and other such resources" [40 CFR § 300.600(a)], as well as "their supporting ecosystems" [40 CFR § 300.600(b)]. In addition to the trustee responsibility set forth in 40 CFR Part 300, the Secretary of the Interior is also charged under other authorities as a trustee for the Indian Trust Assets of tribes. Such trusteeship is impressed upon the United States by statute and case law. “It is the policy of the Department of the Interior to recognize and fulfill its legal obligations to identify, protect, and conserve the trust resources of federally recognized Indian tribes and tribal members . . .” [512 DM 2.1]. The nature and scope of these trust responsibilities have most recently been restated in *Navajo Nation v. United States,* 263 F.3d 1325 (Fed. Cir. 2001). Although the Washoe Tribe is acting as its own trustee, the Secretary of the Interior is a co-trustee for natural resources of the Public Domain Allotments.

By a provision of the Departmental Manual (DM), the Secretary of the Interior has delegated to bureau directors the authority to act on behalf of the Secretary as the Authorized Official in conducting NRDA activities [207 DM 6, paragraph 6.3B]. Furthermore, the Indian Affairs Manual (IAM) states that “directors may exercise all of the program authority of the Commissioner of Indian Affairs necessary to fulfill the responsibilities for those functions, programs and activities assigned to their organizations” [3 IAM chapter 2 (paragraph 2.8), chapter 4 (paragraph 4.4)]. The Western Regional Director of the BIA serves as the Lead Authorized Official for this assessment.

The Secretary of Agriculture is an authorized trustee under the NCP for those natural resources “on, over, or under” national forest lands [40 CFR § 300.605], namely, the Humboldt-Toiyabe National Forest. The Secretary of Agriculture delegated trustee authority to the Chief of the Forest Service [7 CFR § 2.60(a)(42)], and authority has been further delegated to the Regional Forester as per Forest Manual § 2164.04 C-3.

1.2.3 State Trustees

CDFG and NDEP are trustees for the states of California and Nevada, respectively. The NCP provides that “[s]tate trustees shall act on behalf of the public as trustees for natural resources, including their supporting ecosystems, within the boundary of a state or belonging to, managed by, controlled by, or appertaining to such state” [40 CFR § 300.605]. CDFG holds California’s fish and wildlife resources in trust for the people of the state pursuant to California Fish and Game Code section 711.1.

1.3 Completion of Preassessment Screen Determination

In accordance with the NRDA regulations, before deciding whether to initiate a natural resource damage assessment, the Trustees conducted a preassessment screen “to provide a rapid review of readily available information” on trust natural resources that may have been injured by releases of hazardous substances [43 CFR § 11.23(b)]. Based on a preliminary review of readily available data, the Trustees completed the Preassessment Screen Determination (PSD) on July 30, 1998. In accordance with the criteria at 43 CFR § 11.23(e), the PSD supported the conclusion that there is a reasonable likelihood that natural resources have been injured and that the Trustees should conduct an NRDA to develop a damage claim under 42 USC § 9607.

1.4 Natural Resource Damage Assessment Process

This Assessment Plan is designed to be in accordance with the NRDA regulations promulgated by the DOI at 43 CFR Part 11. The use of these regulations is optional, but an NRDA performed in accordance with these regulations is provided a legal evidentiary status of a rebuttable presumption in an administrative or judicial proceeding [43 CFR § 11.10].

The process described in the NRDA regulations involves four major components. The first component is the Preassessment Screen Determination, discussed in Section 1.3.

The second component is the preparation of an Assessment Plan. The Assessment Plan essentially serves as the workplan for the NRDA. The Assessment Plan also includes information that assures that the NRDA is proceeding in a planned, systematic, and cost-effective manner and that various requirements of the regulations are being met.

In the third component, the NRDA is performed. The Type B assessment plan method chosen by the Trustees (see Section 1.5) involves three phases.

1. Injury Determination Phase: The first phase of the assessment determines whether injury to the natural resources has occurred and whether the injury has resulted from the release of hazardous substances.

2. Quantification Phase: The second phase quantifies the injuries and the reduction of services provided by the natural resources. The services provided may include such things as wildlife habitat, recreation, or erosion control.

3. Damage Determination Phase: In the third phase, the monetary compensation for injury is calculated. This will include an RCDP that describes a number of possible alternatives for restoration, rehabilitation, or replacement of the injured natural resources and related services. Because insufficient information is available to develop the RCDP at this time, the RCDP will be completed at a later time, but before completion of the Quantification Phase [see 43 CFR § 11.31(c)(4)]. However, the Trustees have included an RCDP approach as part of this Assessment Plan (see Chapter 6) to provide a conceptual understanding of how the Trustees intend to approach and develop the RCDP.

The fourth component of the NRDA process consists of the post-assessment phase. A Report of Assessment is prepared and made available to the public. The Report of Assessment consists of supporting documentation and the results of the studies performed during the injury determination, quantification, and damage determination phases of the assessment. The PRPs are presented with a demand in writing for a sum certain, representing the damages due to the Trustees. An account is established for the damages assessment awards. Finally, a Restoration Plan is developed and implemented.

The Trustees, in this matter, decided it was more important to gather certain ephemeral data rather than to draft an assessment plan. Response actions were occurring at the site which would likely jeopardize data gathering in future years. The Trustees felt it was important to gather data that accurately depicted the resources and the impacts from the mine before response actions were implemented. Furthermore, the Trustees and ARCO agreed that it was desirable to obtain field data quickly to see if an early resolution of the NRD claim might be achieved. Given funding limitations of the Trustees, it was felt that data could be gathered more quickly with ARCO funding and participating in the data gathering effort. Data obtained from field work already undertaken by the Trustees and ARCO have been considered in designing this Assessment Plan. Prior to development of this Assessment Plan, it also has been necessary to conduct ethnographic studies with Washoe Tribal elders regarding Tribal uses of natural resources in the assessment area prior to development of the open pit mine, as well as in subsequent years. As the number of Washoe elders is declining rapidly, the knowledge they have regarding the baseline natural resource services provided to the Washoe Tribe is of an ephemeral nature, and had to be preserved from irreplaceable loss. In addition, deferring the preparation of the assessment plan has allowed the Trustees to preliminarily review available data and information so as to design this Assessment Plan to avoid duplication and to generally be more efficient and cost effective.

1.5 Decision to Perform a Type B Assessment

Under the DOI's NRDA regulations, the Trustees can elect to perform a Type A or a Type B NRDA [43 CFR § 11.33]. This section documents the Trustees' decision to perform a Type B assessment.

Type A procedures are "simplified procedures that require minimal field observation" [43 CFR § 11.33(a)]. An authorized official may use a Type A assessment only if the released substances are in coastal/marine or Great Lakes environments [43 CFR §§ 11.33, 11.34], making a Type A NRDA inapplicable for the mine assessment area.

In addition, simplified Type A assessment methods would be inappropriate for this NRDA. Releases of hazardous substances in the assessment area are likely to have occurred for over 50 years. Hazardous substances have been transmitted from abiotic natural resources to biota through the food chain, affecting many different trophic levels. Consequently, the releases cannot be considered of a short duration, minor, or resulting from a single event, and therefore are not readily amenable to simplified models. Further, the spatial and temporal extent and heterogeneity of exposure conditions and potentially affected resources are not suitable for application of the simplifying assumptions, averaged data, and conditions inherent in Type A procedures.

The alternative to a Type A procedure is a Type B procedure. Type B procedures require “more extensive field observation than the Type A procedures” [43 CFR § 11.33(b)]. A Type B assessment provides alternative methods for conducting NRDAs and consists of three phases: injury determination, injury quantification, and damage determination [43 CFR § 11.60(b)] (see Chapter 4). Reasonable costs may be incurred in the assessment phase of the Type B damage assessment [43 CFR § 11.60(d)].

The Trustees have determined (1) that the Type A NRDA is not appropriately applied to the long-term, spatially, and temporally complex nature of releases and exposures to hazardous substances characteristic of the mine assessment area; (2) that substantial site-specific data already exist to support the assessment; and (3) that additional site-specific data can be collected at reasonable cost. As a result, the Trustees have concluded that the use of Type B procedures is justified.

1.6 Coordination with Nontrustees

1.6.1 Coordination with response agencies

To the extent possible, a damage assessment should be conducted in coordination with any investigations undertaken as part of NCP response actions, particularly a Remedial Investigation/Feasibility Study (RI/FS) [43 CFR § 11.31(a)(3)]. The Trustees realize that implementing a protective remedy is of primary importance for protection of natural resources. However, based on current information, it is not likely that remediation alone will achieve full restoration of injured natural resources and the services provided by those resources. Moreover, the timing and nature of the remedy selected will affect the extent and duration of continuing injuries to natural resources. Therefore, the amount of restoration required will depend, to a degree, on the remedy selected, the timing of its implementation, and the degree to which it is successful. In general, a less protective remedy will result in greater residual injury to natural resources, a consequent need for more extensive restoration to return the resources to their baseline condition, and greater compensation to make the public whole for the additional services it has lost. For these reasons, the Trustees have coordinated, and will continue to coordinate, with the U.S. Environmental Protection Agency (EPA) on removal actions and the RI/FS process.

To this end, and because coordination among the Trustees is an essential component of a cost-effective damage assessment, the Trustees and the EPA signed a Memorandum of Agreement (MOA), dated April 1998, creating the Leviathan Mine Council (LMC). The MOA and the LMC provide a framework for coordination and cooperation among the Trustees and between the Trustees and the EPA. The Washoe Tribe acts as Lead Administrative Trustee and is the central contact on behalf of the Trustees. The EPA's Remedial Project Manager (RPM) for the Leviathan Mine Superfund Site has participated in the LMC, helping to keep the Trustees informed of ongoing and planned response actions, and soliciting comments from the Trustees on various response action workplans and orders.

The goals of such coordination are to avoid duplication, reduce costs, and achieve dual objectives where possible. At a minimum, the Trustees intend to consider the objectives of removal actions, RI/FS activities, and remedial actions during the continued planning and implementation of the NRDA. Whenever possible, the Trustees will explicitly coordinate damage assessment activities with other investigations and will ensure that appropriate consideration is given to parties undertaking remediation or restoration activities that satisfy the Trustees' NRDA objectives. At present, the EPA's RPM has estimated that a Record of Decision selecting a remedy for the Leviathan Mine Superfund Site will not be signed until before 2005.

1.6.2 Coordination with PRPs

To coordinate with the PRPs and to reduce the burden on the Trustees' financial resources, the Trustees entered into a Funding and Participation Agreement with ARCO in September 1998 (Washoe Tribe et al., 1998). Under this agreement, the Trustees and ARCO conducted a number of preliminary natural resource damages studies. However, in March 1999, ARCO declined to extend the agreement, in part because the EPA began moving toward proposing the mine for listing on the National Priorities List (NPL; Stash, 1999). The Trustees' subsequent invitations to ARCO to continue to participate under the agreement were not accepted. The Trustees remain open to, and encourage, ARCO's participation in the development and implementation of the NRDA, including coordination with ARCO's removal action and RI/FS activities.

In part because the LRWQCB has limited funding with which to conduct its response actions, the Trustees have not sought to enter into a similar funding agreement with the LRWQCB.

1.6.3 Public review and comment

This Assessment Plan is available for public review and comment. Comments must be received within 30 days from the date the notice of availability is published in the Federal Register. Comments may be submitted in writing to:

Mr. Wayne Nordwall
Regional Director
U.S. Bureau of Indian Affairs
Western Regional Office
P.O. Box 10
Phoenix, AZ 85001

for overnight mail only:
400 North Fifth Street
Phoenix, AZ 85004

Fax: (602)379-4413

The Trustees may amend the Assessment Plan, and any significant amendments will be made available for public review [43 CFR § 11.32(e)].

2. Description of the Assessment Area

2.1 Geographical Areas Involved

2.1.1 Definitions of geographic terms

Leviathan Mine property: The legal property to which the State of California, Lahontan Regional Water Quality Control Board (LRWQCB) holds legal title.

Leviathan Mine Superfund Site (the site): The "area or location, for purposes of response actions under the NCP, at which . . . hazardous substances have been stored, treated, . . . released, disposed, placed, or otherwise came to be located" [43 CFR § 11.14(oo)], which in this case extends well beyond the mine property.[1]

Assessment area: "The area or areas within which natural resources have been affected directly or indirectly by the . . . release of a hazardous substance and that serves as the geographic basis for the injury assessment" [43 CFR § 11.14(c)], namely, the Leviathan Creek, Aspen Creek, and Bryant Creek watersheds, the East Fork of the Carson River, and any other areas containing natural resources potentially injured by hazardous substances released from the mine.

Because the assessment area covers areas of indirect and direct effects of releases, it may extend further than the boundaries of the response action site, which reaches only as far as where the hazardous substances have come to be located. To illustrate the relationship of the three above terms, from narrow to broad:

$$\textit{property} < \textit{site} \leq \textit{assessment area}$$

2.1.2 The assessment area

The actual mine property, currently owned by the State of California, LRWQCB, covers 656 acres in Alpine County, California, on the eastern flank of the central Sierra Nevada, roughly 6 miles east of Markleeville, California, near the Nevada state border (Figure 2.1). The physical disturbance from mine operations covers approximately 253 acres of the property, as well as approximately 21 acres of National Forest Service (NFS) lands under USFS jurisdiction (EPA, 2000a, paragraph 5).

1. For a fuller explanation of the difference between property and site boundaries in general, see 65 Fed. Reg. 30482, 30483 (May 11, 2000).

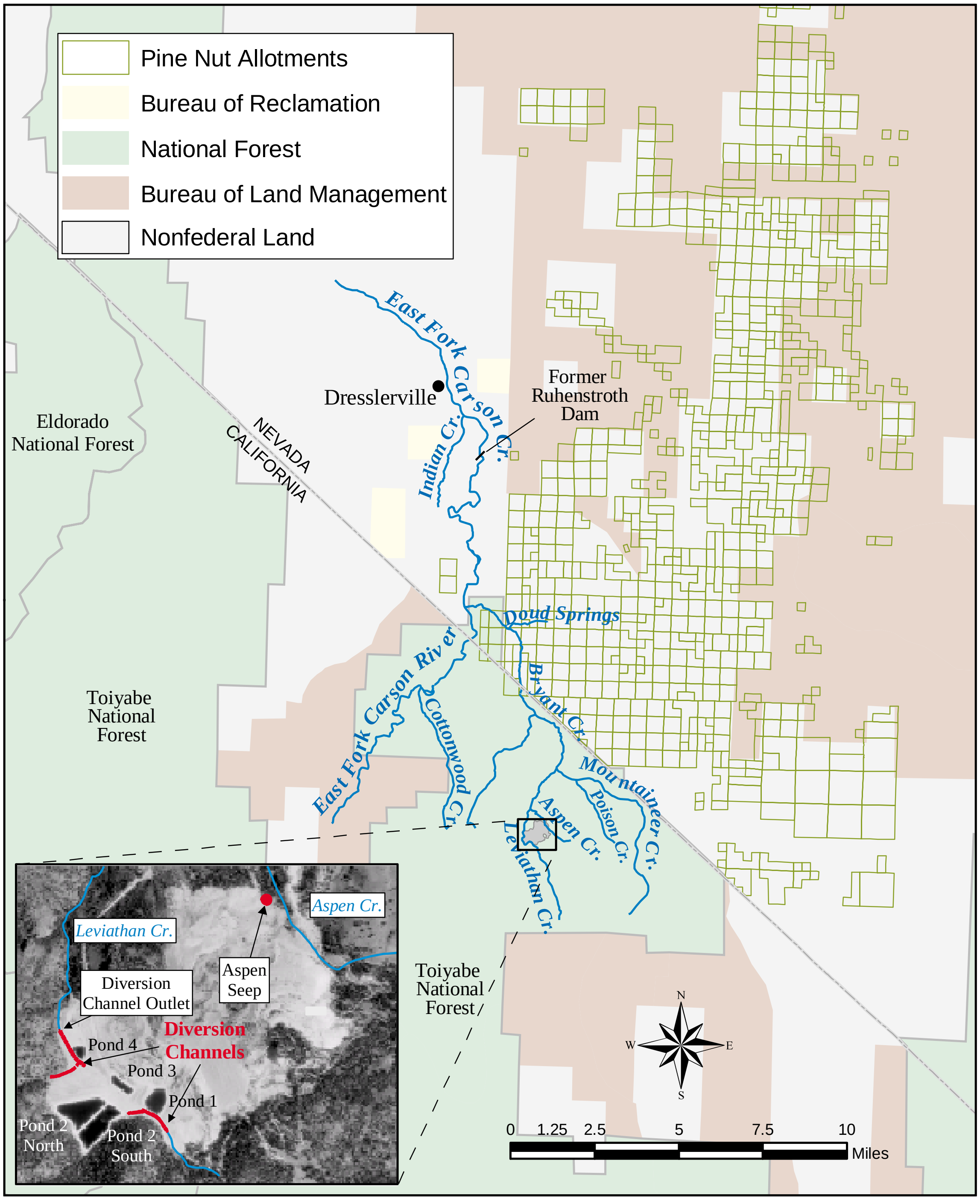

Figure 2.1. Leviathan Mine and surrounding area. Inset map shows details of mine site.

Hazardous substances are released directly from the mine property into both Leviathan Creek and Aspen Creek, which then feeds into Leviathan Creek a short distance downstream. Leviathan Creek joins with Mountaineer Creek approximately 2½ miles downstream of the mine property to form Bryant Creek. Bryant Creek crosses the Nevada state border and empties into the East Fork of the Carson River approximately 7 miles downstream from the confluence of Leviathan and Mountaineer. From the confluence with Bryant Creek, the East Fork travels approximately 10 miles before passing through the Washoe Tribe's Dresslerville Indian Colony. The Leviathan Creek watershed (including the 2 miles upstream of the mine) is approximately 10.5 square miles. The confluence of Leviathan Creek and Mountaineer Creek forms the start of Bryant Creek, which has a 31.5 square mile watershed.

The Leviathan Mine Superfund Site lies within the 6.5 million acres of land, including numerous water sources, that comprise the aboriginal territory of the Washoe Tribe [*Washoe Tribe v. United States*, 21 Indian Claims Comm'n. 447 (1969)]. Furthermore, the Bryant Creek drainage contains over 10,000 acres of Public Domain Indian Trust Allotments, commonly known as the Pine Nut Allotments, of which at least the 12 allotments through which Bryant Creek flows may be impacted directly as a result of releases from the mine. Other potentially impacted tribal land includes Dresslerville, a 795-acre parcel of the Washoe Reservation that includes the community of Dresslerville, the Washoe Ranch, and a campground facility. Dresslerville is located along the East Fork of the Carson River, approximately 20 miles downstream of the mine.

The Humboldt-Toiyabe National Forest surrounds and lies directly downstream of the mine. Approximately one-half of the downstream property between the mine and Dresslerville is National Forest Service (NFS) land.

2.2 History of Leviathan Mine

2.2.1 Pre-open-pit mining

The Leviathan Mine was first worked by Comstock Lode miners, who between 1863 and 1870 removed 500 tons of 30 to 50% copper sulfate for use in silver ore refining through two adits (horizontal underground workings). Soon thereafter, the miners abandoned the mine upon discovering that the second adit was above an immense sulfur deposit, not the primary copper minerals in which they were interested (Schoen et al., 1995, p. 5). Sometime before 1935, the Texas Gulf Sulfur Company obtained a lease of the mine property, though it is unclear who the owner was. In 1935, Texas Gulf subleased the mine property to the Calpine Corporation of Los Angeles, which from 1935 to 1941 conducted subsurface sulfur mining through three more adits. In 1941, after producing about 5,000 long tons of sulfur, Calpine gave up its sublease because of the hazardous nature of underground sulfur mining (Taxer et al., 1991, p. 3; Schoen et al., 1995,

p. 5). A subsidiary of Texas Gulf, Siskon Mining Corporation, acquired the mine in 1945 (California Division of Mines and Geology, 1977, p. 35).

2.2.2 Open pit mining by Anaconda

In 1951, Anaconda Copper Mining Company purchased the mine as a source of sulfur for processing copper ore at Anaconda's Weed Heights Mine near Yerington, Nevada. Anaconda developed the former underground mine into an open pit mine, ultimately excavating a 400-foot deep pit stretching over approximately 50 acres (2,000 feet long and 1,000 feet wide). Between 1953 and 1962, Anaconda extracted approximately 500,000 long tons of sulfur from the mine (Schoen et al., 1995, p. 6).

Infiltration of precipitation into and through the open pit and overburden piles created acid mine drainage (AMD), which discharged directly into Leviathan Creek. Contact with waste piles deposited directly into the creek also contaminated Leviathan Creek. Releases of AMD from the site resulted in fish kills in Leviathan and Bryant Creeks and the East Fork Carson River (Trelease, 1959, p. 6).

Anaconda's development of the open pit mine led to the formation and release of AMD into Leviathan and Aspen Creeks from several sources: the overburden and waste rock dumped into the creek channels, unnatural seeps created by precipitation through the overburden disposed of around the pit and the waste rock dump, and groundwater flows through ore under the open pit, enhanced by precipitation collected and infiltrated in the open pit (Brown and Caldwell, 1983, pp. 2-3, 2-30). At least two major, acute fish kills occurred due to large releases of AMD from Leviathan Mine. The first fish kill resulted from an old mine tunnel collapsing during overburden removal, releasing a large slug of AMD into Leviathan Creek (Schoen et al., 1995, p. 11). Various sources place this first fish kill in either 1952 (LRWQCB, 1975, pp. III-2, IV-1) or 1954 (Schoen et al., 1995, p. 11; Brown, 1968); it is unclear at this time which date is correct. Continuous discharges of AMD from Anaconda's open pit mining operations appear to have decimated the trout fisheries in Bryant Creek and in the East Fork of the Carson River at least 10 miles downstream from Bryant Creek before late November 1959 (LRWQCB, 1975, p. III-2). Thus, few trout remained to be killed during the 1959 fish kill that claimed an estimated 10,000-20,000 other fish in Bryant Creek and in the East Fork (LRWQCB, 1975, p. III-2) at least as far downstream as the Washoe Indian community of Dresslerville (Trelease, 1959, p. 1). This second fish kill occurred when Anaconda's AMD containment pond dike failed, releasing approximately 5 million gallons of AMD into Leviathan Creek (Schoen et al., 1995, p. 11).

Anaconda ceased its mining operations near the end of 1962, and in January 1963, sold the mine property to William Chris Mann (the Alpine County Clerk) and Zella N. Mann, who helped form Alpine Mining Enterprises (LRWQCB, 1975, p. III-7; Brown and Caldwell, 1983, p. 2-4; Schoen et al., 1995, p. 6). Shortly before the sale, the LRWQCB had requested that Anaconda apply for a permit for its controlled discharges of AMD from retention ponds to Leviathan Creek (Taxer et al., 1991, p. 7).

2.2.3 Acquisition of mine and operation of pollution abatement project by California

In January 1984, the State of California acquired ownership of the mine property from Alpine Mining Enterprises. Jurisdiction over the mine property was transferred to the State Water Resources Control Board. From 1983 (before California's acquisition of the site) to 1985, the LRWQCB built the Leviathan Mine Pollution Abatement Project in an attempt to deal with the AMD generated by past mining operations (Schoen et al., 1995, pp. 27-28).

Major elements of the LRWQCB's Pollution Abatement Project included the following:

- Filling and regrading the open pit (Schoen et al., 1995, p. 33).

- Installing a series of drains beneath the pit itself and by the adit portal of the fifth adit (which was never breached during the excavation of the pit) to capture water flowing through these areas (SRK Consulting, 1998, pp. 2-5 to 2-6).

- Constructing five evaporation ponds (1, 2-North, 2-South, 3, and 4) with a surface area of about 11.4 acres to collect and evaporate the AMD-contaminated surface and groundwater from the pit and adit portal underdrains and from other sources (Schoen et al., 1995, pp. 31-32, 48-49); Ponds 1, 2-North, 2-South, and 3 drain into Pond 4.

- Channelizing Leviathan Creek to separate uncontaminated surface water from the waste ore and the AMD-contaminated groundwater flowing from the mine to Leviathan Creek (Schoen et al., 1995, pp. 30-31).

During construction of part of the trench for the channelized portion of Leviathan Creek, many acidic springs were discovered. The LRWQCB built a drain line, the channel underdrain, to direct this seepage, which resulted in an AMD discharge directly into Leviathan Creek (Schoen et al., 1995, p. 30).

2.2.4 Involvement by the EPA and subsequent response actions

The LRWQCB's Pollution Abatement Project did not eliminate the releases of hazardous substances and actually redirected several sources of AMD to new discharge points, including the channel underdrain and Pond 4, which periodically overflowed into Leviathan Creek. EPA Region IX first attempted a removal action at the mine in the fall of 1997, when the EPA's

Office of Emergency Response made an unsuccessful attempt to install a lime neutralization treatment to reduce the toxic content of the AMD evaporation ponds (Mayer, 2001, sec. II. B.).

In 1998, ARCO, the successor in interest to its wholly owned subsidiary, Anaconda, conducted a removal action pursuant to an Administrative Order on Consent (AOC) issued by the EPA (EPA, 1998a). Under the AOC, ARCO was to provide 8.5 million gallons of freeboard capacity in the evaporation ponds to prevent pond overflow of AMD into Leviathan Creek (EPA, 1998a, pp. 4-5). However, as noted by the EPA (Mayer, 2001, sec. II. B.):

> AERL [ARCO Environmental Remediation, L.L.C.] relied upon unproven technologies and encountered challenging site logistics during the short summer season at the Site. By November, 1998, only 3 million gallons of storage capacity had been achieved, and by January, 1999, the ponds had filled and were discharging AMD to Leviathan Creek. Between January and July, 1999, nearly 9 million gallons of untreated AMD overflowed into Leviathan Creek.

In 1999, the LRWQCB implemented its own workplan for the site, including installing and operating a biphasic neutralization water treatment plant to treat AMD in the evaporation ponds with the hope of minimizing the possibility of pond overflows into Leviathan Creek (Mayer, 2001, sec. II. B.). The biphasic process is basically a two-step lime neutralization treatment, in which the pH first is raised to the point where iron is precipitated out in the form of ferric hydroxide and arsenic co-precipitates with the ferric hydroxide. The resulting Phase I sludge meets the California classification for hazardous waste and must be disposed of at an appropriate facility. However, in the second step, the pH is raised to a greater degree, precipitating additional metals. The larger amount of Phase II sludge is not classified as hazardous and has been stored on-site. The treated effluent is then discharged to Leviathan Creek (LRWQCB, 2000, p. 4). As a result of the biphasic treatment, combined with evaporation and decanting of relatively clean snowmelt from the ponds, no pond overflow occurred in 2000 (Mayer, 2001, sec. II B).

The EPA proposed to add the mine site to the NPL [40 CFR Part 300, Appendix B] on October 22, 1999 [64 Fed. Reg. 56992]. The EPA provided notice of the proposed listing to the chairman of the Washoe Tribe and to the governors of California and Nevada. The Washoe Tribe; Alpine County, California; the State of Nevada; Douglas County, Nevada; and the Carson River Conservancy District all submitted comments to the EPA in support of listing the mine on the NPL. On May 11, 2000, the EPA added the mine site to the NPL [65 Fed. Reg. 30482] pursuant to section 105 of CERCLA [42 USC § 9605].

The EPA issued an Administrative Abatement Action to the LRWQCB on July 19, 2000, under which the LRWQCB continued to operate the biphasic treatment and conduct other activities at the site, including water quality monitoring (EPA, 2000a). The EPA also issued a Unilateral Administrative Order to ARCO on November 22, 2000, under which ARCO is to develop long-term response plans, including an RI/FS, in addition to conducting Early Response Actions (EPA, 2000a).

2.3 Hazardous Substances Released

2.3.1 Sources and releases

Releases of hazardous substances from the mine began as early as the 1950s, when Anaconda Company transformed the underground workings into an open pit mine to extract the sulfur ore. During the open pit mining operation, at least 22 million tons of overburden[2] and waste rock[3] (including a substantial amount of low-grade sulfur ore) were removed from the pit and deposited over more than 200 acres "without any classification, separation, or original ground surface preparation" at various spoil areas around the pit (Schoen et al., 1995, p. 6). Surface runoff during spring snowmelt and precipitation coming in contact with this material generated sulfuric acid, which then leached heavy metals from the ore (Taxer et al., 1991, p. 5). A 26-acre, 130-foot deep, waste rock dump was formed directly in the canyon of Leviathan Creek (Schoen et al., 1995, p. 6; SRK Consulting, 1998, p. 2-6, fig. 2.1). The creek flowed into this waste rock dump, causing the creek to seep through and flow around the waste rock (Schoen et al., 1995, p. 6), which has a higher degree of mineralization, including copper and sulfur ore, than overburden spoil areas (EPA, 1999a, pp. 28, 40). Anaconda's attempt to keep Leviathan Creek from coming in contact with the waste rock by diverting it around the waste rock dump was not very successful, because high spring runoffs often washed out the diversion ditch (Brown and Caldwell, 1983, p. 2-3).

Releases of hazardous substances continue. Several sources at the mine currently release various hazardous substances into the groundwater and the water and sediment in Leviathan Creek and Aspen Creek, and from there into Bryant Creek and the East Fork of the Carson River. Principal sources of AMD released into Leviathan Creek include the channel underdrain (collecting seeps from underneath the channelized portion of Leviathan Creek), the Aspen Seep (a seep passing through waste rock and overburden to the northeast of the pit), the Delta Seep (a seep through a waste dump to the north of the channelized portion of Leviathan Creek), and possibly additional groundwater sources (see Figure 2.1). Another significant release source has been AMD overflow from the evaporation ponds (fed mainly by the pit and adit portal underdrains) via Pond 4 (Mayer, 2001, sec. II. B.). As the ponds continue to fill with AMD, pond overflow remains a potential source. Additional sources of hazardous substance releases from the mine

2. Overburden is rock that is removed to create a pit to access the ore in open pit mining.

3. Waste rock is rock left over from mining after removal of the overburden.

may include, but are not limited to, other seeps passing through waste rock and overburden piles, surface water runoff and soil erosion, and adits, tunnels, pipes, channels, and shafts. Moreover, it is likely that sediments contaminated by hazardous substances continue to rerelease hazardous substances into the water bodies. Hazardous substances may also have been released, and may continue to be released, via air pathways from the mine property, the mine road, and the water bodies. Overburden may have been used in constructing the mine road, which goes through State of California, USFS, Indian trust allotment, and State of Nevada lands.

The AMD evaporation ponds that were built as part of the LRWQCB's Leviathan Mine Pollution Abatement Project were designed to overflow primarily during times of high flows in Leviathan Creek (Taxer et al., 1991, p. 10; Schoen et al., 1995, pp. 32, 40). As a result, Pond 4 has overflowed intermittently, with overflows being the highest in the spring and early summer and lowest toward the end of summer, when evaporation tends to exceed inflow to the ponds. In years of average precipitation, Pond 4 overflowed approximately 3 million gallons of AMD (EPA, 1999a, p. 20). However, in some years overflows were much larger. For example, from January through June 1998, Pond 4 released approximately 7.12 million gallons of untreated AMD into Leviathan Creek (LRWQCB, 1998). Largely because of low precipitation and the operation of the LRWQCB's biphasic treatment, there were no pond overflows in 2000 (Mayer, 2001, sec. II. B.).

In addition, the channel underdrain continuously releases AMD into Leviathan Creek. From January through June 1998, the channel underdrain released approximately 11.19 million gallons of AMD directly into Leviathan Creek. During that same period, the Aspen Seep released an estimated 4.25 million gallons of AMD into Aspen Creek (which flows into Leviathan Creek) (LRWQCB, 1998). Together, an estimated 22.56 million gallons of AMD were known to have been released from Pond 4, the channel underdrain, and Aspen Seep during those 6 months.

In addition, Delta Seep releases AMD into Leviathan Creek at approximately 10 gpm (EPA, 2000b, paragraph 15), though flow measurements were not compiled for Delta Seep during that time period.

2.3.2 Hazardous substances

Those hazardous substances, as listed in 40 CFR Part 302.4, that have been released include, but may not be limited to, the substances and compounds identified in Table 2.1.

AMD generated at the mine is formed when water percolates through mineralized rock made accessible and permeable by construction of the mining adits and especially by development of the open pit. Oxidation and hydration of sulfur and sulfur minerals in the main ore body, and in the discarded overburden and waste rock, create sulfuric acid, ferrous sulfate, and other metal

Table 2.1. Hazardous substances released at the Leviathan Mine.

Hazardous substance	Reference
Aluminum sulfate	Brown and Caldwell, 1983, p. 2-23
Arsenic and compounds	EPA, 1999a, p. 12, Table 1
Beryllium and compounds	EPA, 1999a, p. 12, Table 1
Cadmium and compounds	EPA, 1999a, p. 12, Table 1
Chromium and compounds	EPA, 1999a, p. 12, Table 1
Cobalt compounds	EPA, 1999a, p. 12, Table 1
Copper and compounds	EPA, 1999a, p. 12, Table 1
Ferric sulfate and ferrous sulfate	Brown and Caldwell, 1983, p. 2-23; EPA, 1999a, p. 8
Lead and compounds	SRK Consulting, 1999, Table 4.2
Manganese compounds	EPA, 1999a, p. 12, Table 1
Mercury and compounds	SRK Consulting, 1999, Table 4.2
Nickel and compounds	EPA, 1999a, p. 12, Table 1
Selenium and compounds	SRK Consulting, 1999, Table 4.2
Sulfuric acid	LRWQCB, 1975, p. V-4; EPA, 1999a, p. 8
Thallium and compounds	EPA, 1999a, p. 12, Table 1
Zinc and compounds	EPA, 1999a, p. 12, Table 1

sulfates. AMD also typically contains the other hazardous substances listed in Table 2.1, because the sulfuric acid and low pH water leach the heavy metals from the ore (LRWQCB, 1975, p. V-4; Brown and Caldwell, 1983, pp. 2-3, 3-17 to 3-18).

Furthermore, AMD released from the mine may at times qualify as a hazardous substance itself, regardless of its constituents. When the pH of the AMD is equal to or less than 2, it satisfies the corrosivity test of the Resource Conservation and Recovery Act (RCRA) [42 USC § 6921; 40 CFR § 261.22(a)(1)] and is incorporated as a hazardous substance under CERCLA [42 USC § 9601(14)(C); 40 CFR § 302.4(b)] (EPA, 1999a, p. 11). Samples collected from the adit and pit drainage in 1981 and 1982 ranged from pH 1.8 to 2.8 (EPA, 1999a, p. 11).

2.4 Potentially Affected Natural Resources

The DOI regulations define five categories of natural resources for purposes of assessing natural resource damages: surface water resources, groundwater resources, air resources, geologic resources, and biological resources. The following sections briefly describe each of these categories in the context of the assessment area. As further information becomes available, the

Trustees may decide not to pursue an assessment for each of these natural resources; however, restoration planning will most likely address more than one resource at a time.

2.4.1 Surface water resources

Surface water resources in the assessment area include the water, streambed, and bank sediments of Leviathan Creek, Bryant Creek, Aspen Creek, and the East Fork of the Carson River from the confluence with Bryant Creek and downstream at least as far as the Dresslerville Indian Colony just south of Gardnerville, Nevada.

These resources are particularly important in the context of this damage assessment, because they have been and continue to be the principal receptors of hazardous substances released to the environment within the assessment area. The contamination of these resources has both direct and indirect impacts on the health of biological resources. For example, contaminated sediments can cause injury to benthic invertebrate populations, which in turn can result in injuries to resident fish populations for whom the invertebrates are a source of food. Similarly, injury to invertebrates and/or fish resulting from exposure to contaminated sediments and surface water can lead to injury in local insectivorous or piscivorous bird populations. In addition, contaminated sediments serve as a source of continuing releases of hazardous substances to the water column.

2.4.2 Groundwater resources

There has not been an extensive amount of data gathered about local aquifer characteristics. However, limited groundwater investigations indicate that groundwater predominantly flows from the south of the mine property, heading northwest under the western part of the open pit. The groundwater level there is fairly close to the surface, with surface and subsurface flows from the area of the pit and adit infiltrating into the groundwater. The local groundwater gradient carries this groundwater west toward Leviathan Creek near the waste dump and delta (where the Delta Seep is located; Brown and Caldwell, 1983, p. 2-30). During spring snowmelt and runoff, the groundwater at the delta/waste dump most likely contributes to Leviathan Creek, while Leviathan Creek most likely recharges the groundwater during summer (Brown and Caldwell, 1983, p. 2-31). Despite some efforts at regrading the pit to prevent infiltration, contaminated groundwater continues to discharge to Leviathan Creek (Schoen et al., 1995, pp. 30-33).

2.4.3 Air resources

Air resources may have been injured by releases of particulate or gaseous hazardous substances from overburden and waste rock (EPA, 1999a, p. 28), AMD evaporation ponds (EPA, 1999a,

p. 19), creeks, floodplain soils, and the mine road, which may have been at least partially constructed from overburden. The Trustees do not have sufficient data at this time to determine that an assessment of air resources would be cost-effective, and thus methods for evaluating injury will not be discussed in this document. Additional data may be generated through the risk assessment conducted during the RI/FS. Pending additional information, the Trustees may determine that an assessment of air resources should be undertaken.

2.4.4 Geologic resources

Geologic resources are primarily the floodplain soils along Leviathan Creek, Bryant Creek, and Aspen Creek, and the East Fork of the Carson River, at least as far as Dresslerville. Floodplain soils are likely to have been injured as contaminated water and sediment from the creeks flooded the banks. Injury to floodplain soils may also affect riparian vegetation and wildlife, particularly small mammals.

2.4.5 Biological resources

A number of potentially injured biological resources have existed in the assessment area, including, but not limited to:

- fish of a number of species, particularly various species of trout
- benthic invertebrates
- riparian, riverine, wetland, and upland habitats supporting fish and wildlife
- riparian vegetation
- mammalian, amphibian, reptilian, and avian wildlife species, including migratory birds, and various rodents.

The Lahontan cutthroat trout (*Oncorhynchus clarki henshawi*), a threatened species under the Endangered Species Act [16 USC § 1531], exists in portions of the watersheds in the vicinity of the mine and the East Fork Carson River downstream as far down as Dresslerville, Nevada. The bald eagle (*Haliaeetus leucocephalus*), also a threatened species under the ESA, exists in nearby watersheds and may exist in the vicinity, as well. Moreover, a number of mammals, birds, amphibians, reptiles, and invertebrates in the area have been designated by USFWS as species of concern (USFWS, 2001).

3. Confirmation of Exposure

This chapter presents data confirming that natural resources have been exposed to hazardous substances released from the mine.

The DOI NRDA regulations state that an assessment plan should confirm that:

> at least one of the natural resources identified as potentially injured in the preassessment screen has in fact been exposed to the . . . hazardous substance [43 CFR § 11.37(a)].

A natural resource has been exposed to a hazardous substance if "all or part of [it] is, or has been, in physical contact with . . . a hazardous substance, or with media containing the . . . hazardous substance" [43 CFR § 11.14(q)]. The DOI regulations also state that "whenever possible, exposure shall be confirmed using existing data" from previous studies of the assessment area [43 CFR § 11.34(b)(1)].

Hazardous substances released from the mine include various toxic metals such as arsenic, cadmium, copper, nickel, and zinc, and acidity (see Chapter 2). The following sections provide confirmation of exposure to hazardous substances, based on a review of the available data, for a number of natural resources in the assessment area:

- surface water
- sediments
- groundwater
- biological resources (including benthic macroinvertebrates, fish, riparian habitat, and terrestrial wildlife).

Air and floodplain soils may also be exposed to hazardous substances. These resources are not evaluated at this time because of a lack of readily available data.

3.1 Data Sources

Data confirming exposure to hazardous substances have been collected by multiple parties in the mine area. Samples have been collected in stream reaches downstream of the mine, in Leviathan Creek, Aspen Creek, Bryant Creek, and the East Fork Carson River (Figure 3.1). Because these sites are potentially influenced by the mine, they are classified as assessment reaches. In addition, samples have been collected in stream reaches that are not influenced by the mine, in

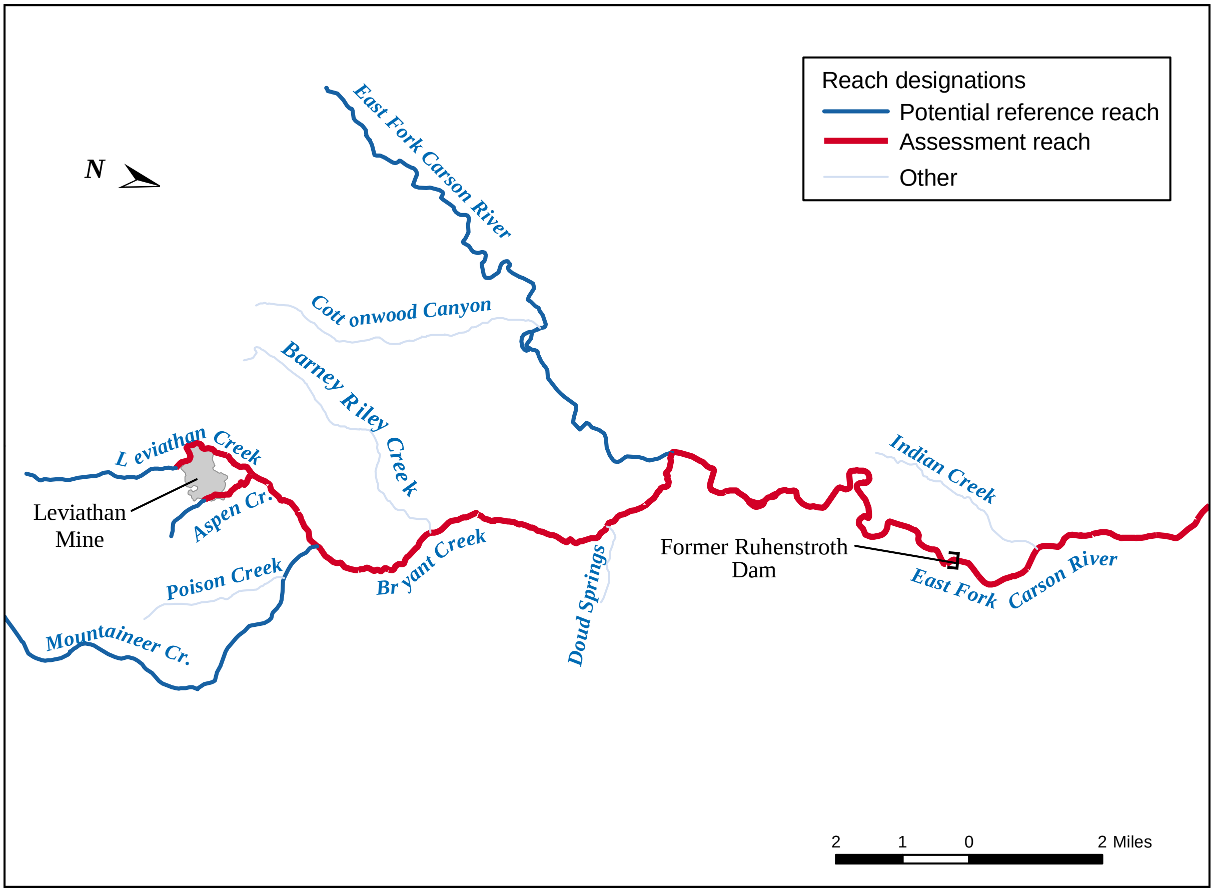

Figure 3.1. Reaches in the Leviathan mine area where samples have been collected and other stream reaches for reference. Potential reference reaches are those that are upstream of influence from the mine. Assessment reaches are those that are downstream of the mine. Note compass orientation of map (stream flow is generally south to north, oriented as left to right on map) used for presentation purposes.

Leviathan Creek and Aspen Creek upstream of the mine, in Mountaineer Creek, and in the East Fork Carson River upstream of the confluence with Bryant Creek. Although these sites have not been thoroughly evaluated for their appropriateness as reference locations, for the purposes of this confirmation of exposure, they are considered potential reference reaches.

The following data sources are used in this report to confirm exposure of natural resources:

- Surface water quality has been monitored by the LRWQCB in the area of the mine and in several upstream and downstream locations. Currently available data include samples collected from the fall of 1997 through the fall of 1999 (LRWQCB, 1999). Undetected constituents within samples from this data set with detection limits above the lowest detection limit for each analyte were not included in analysis, as high detection limits are potentially unreliable.

- Surface water and sediment samples were collected at 14 corresponding locations by the U.S. Geological Survey (USGS) in September 1998 (Thomas and Lico, 2000). Sampling locations extended from upstream of the mine to the East Fork Carson River.

- Groundwater was sampled in 15 wells installed in the Leviathan Creek drainage area by SRK Consulting (SRK Consulting, 1999). Sampling for metal concentrations and other water quality parameters was conducted in October and November 1998.

- The USFWS prepared a study of aquatic natural resources in September 1998 (Thompson and Welsh, 1999). This study included analysis of aquatic invertebrate tissue at points upstream and downstream of the mine site as far as the East Fork Carson River. In addition, fish tissue samples were collected in the East Fork Carson River upstream and downstream of Bryant Creek.

- A follow-up study conducted in April 1999 by the USFWS included surface water quality data at nine locations downstream of the mine and three locations upstream of the mine (Thompson and Welsh, 2000).

3.2 Surface Water Resources

Surface water resources are defined in the DOI regulations as including both surface water and sediments suspended in water or lying on the bank or bed [43 CFR § 11.14(pp)]. Available data on metal concentrations and acidity confirm that these resources are exposed to the following hazardous substances at the mine site: acidity (measured as low pH), arsenic, cadmium, copper, nickel, and zinc.

Metal concentrations and pH in surface water were measured by the LRWQCB (LRWQCB, 1999), the USFWS (Thompson and Welsh, 2000), and the USGS (Thomas and Lico, 2000) from 1997 to 1999. Filtered samples are presented to describe the dissolved concentration of metals in surface water.

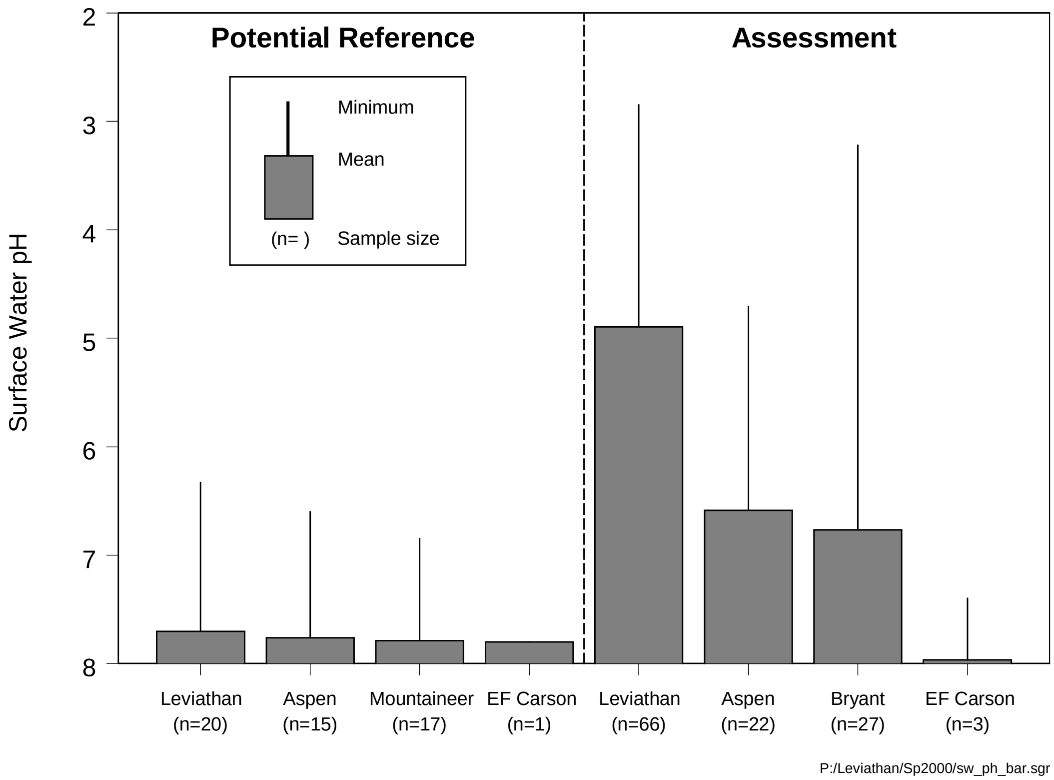

Figure 3.2. Surface water pH in potential reference and assessment reaches of Leviathan mine area. Note that the y-axis is inverted to reflect increasing acidity at lower pH values.

Sources: LRWQCB, 1999; Thomas and Lico, 2000; Thompson and Welsh, 2000.

Confirmation of exposure to acidity and metals is provided by available data: pH is depressed and metal concentrations are elevated in surface water in downstream assessment reaches compared to samples collected in potential reference reaches upstream of the mine (Figures 3.2 to 3.7). For example, the minimum pH measured in potential reference reaches of Aspen Creek, Leviathan Creek, Mountaineer Creek, and the East Fork Carson River was 6.3 (Figure 3.2). In contrast, the minimum pH in the Leviathan Creek assessment reach was 2.9. The Aspen Creek and Bryant Creek assessment reaches also had low pH, with minimum measurements of 4.7 and 3.2, respectively. These data confirm exposure within these reach locations. Available data were not sufficient to confirm low pH exposure in the East Fork Carson River. However, since Bryant Creek flows into the East Fork Carson River, and at least one fish kill occurred in the East Fork River in 1959 (see Chapter 2), exposure to acidity is possible.

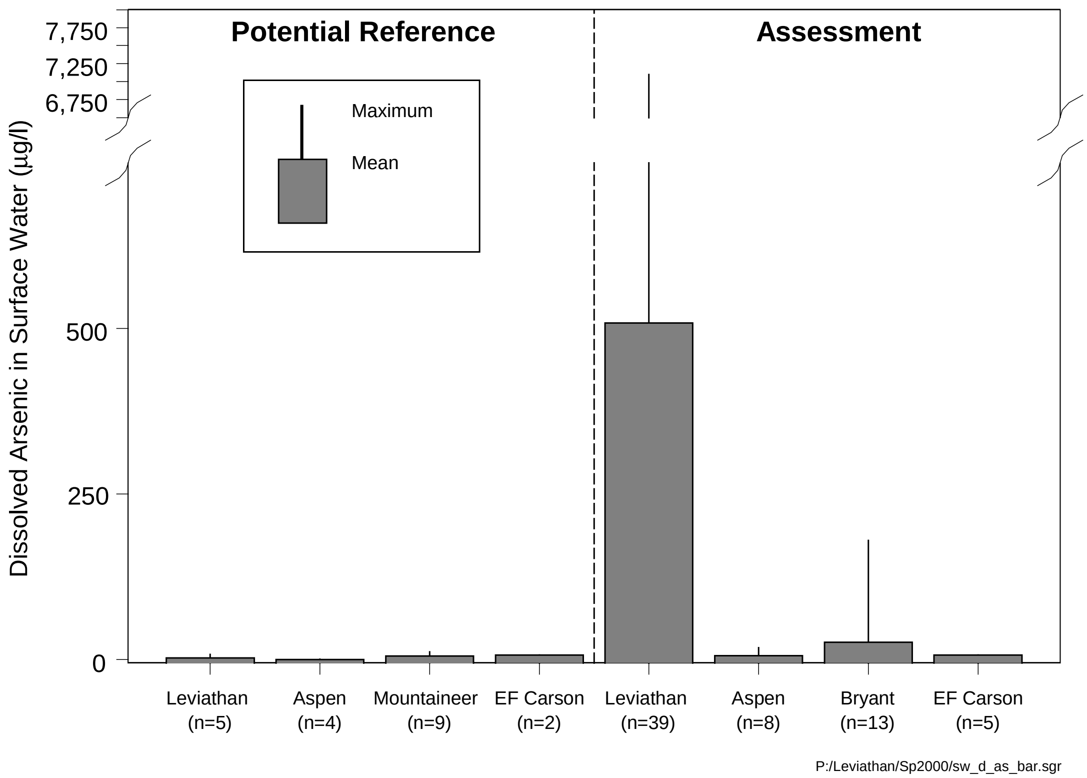

Figure 3.3. Surface water dissolved arsenic in potential reference and assessment reaches of Leviathan mine area. Samples reported as nondetected are plotted at one-half the analytical detection limit.

Sources: LRWQCB, 1999; Thomas and Lico, 2000; Thompson and Welsh, 2000.

Maximum dissolved arsenic concentrations measured in the Leviathan Creek assessment reach were up to three orders of magnitude greater than those measured in potential reference reaches (Figure 3.3). Arsenic was detected in 13 out of 20 samples from potential reference reaches, and 33 out of 39 samples in the Leviathan Creek assessment reach.[1] The maximum detected arsenic concentration measured in the Leviathan Creek assessment reach was 7,100 µg/L, compared to 12 µg/L in potential reference reaches. Maximum arsenic concentrations were elevated in the Bryant Creek assessment reach compared to potential reference reaches by approximately one order of magnitude, and were slightly elevated in the Aspen Creek assessment area.

1. The detection limit for dissolved arsenic was 1.0 µg/L in USGS samples, 0.5 µg/L in USFWS samples, and 0.5 µg/L in LRWQCB samples.

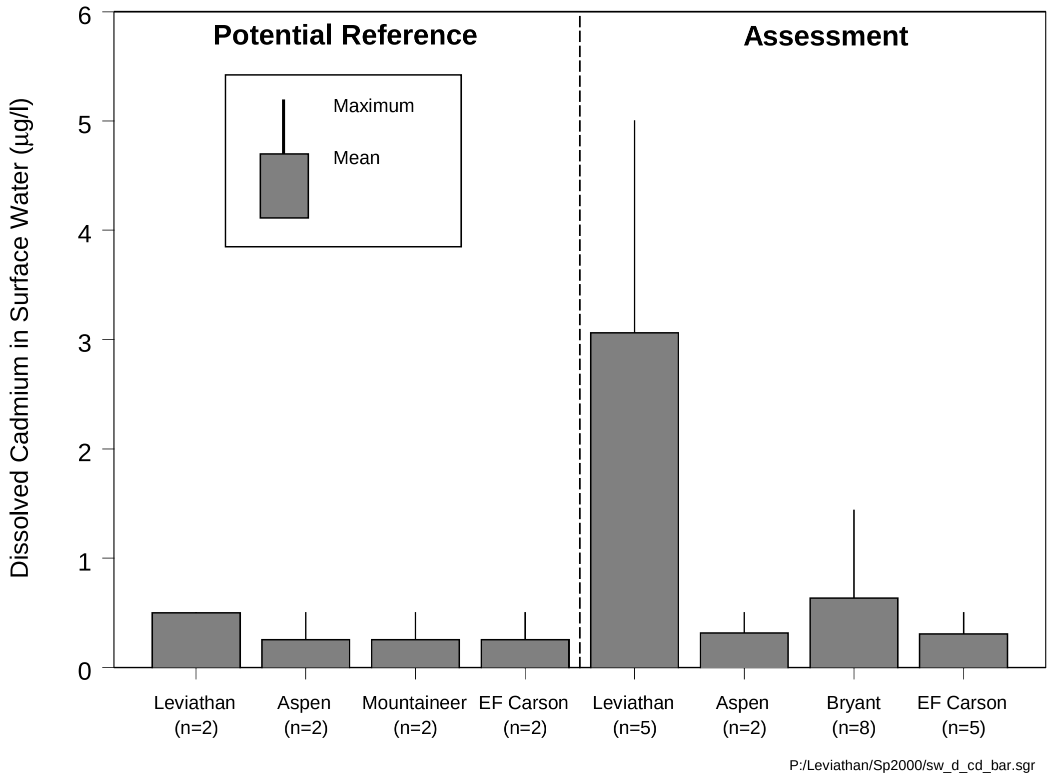

Figure 3.4. Surface water dissolved cadmium in potential reference and assessment reaches of Leviathan mine area. Samples reported as nondetected are plotted at one-half the analytical detection limit.

Sources: Thomas and Lico, 2000; Thompson and Welsh, 2000.

The Lahontan Regional Water Quality Board did not analyze samples for cadmium; however, samples collected by the USFWS and the USGS indicate that surface water resources have been exposed to cadmium as well (Figure 3.4). Dissolved cadmium was not detected in any of the eight samples collected in potential reference reaches.[2] Three of the five samples in the Leviathan Creek assessment reach had detectable cadmium, with a maximum concentration of 4.18 µg/L. The maximum concentration in the Bryant Creek assessment reach was 1.44 µg/L. Only two samples were analyzed for cadmium in the Aspen Creek assessment reach, and one sample had detectable cadmium, at a concentration of 0.13 µg/L.

2. The detection limit for dissolved cadmium was 1.0 µg/L in USGS samples, and 0.02 µg/L in USFWS samples.

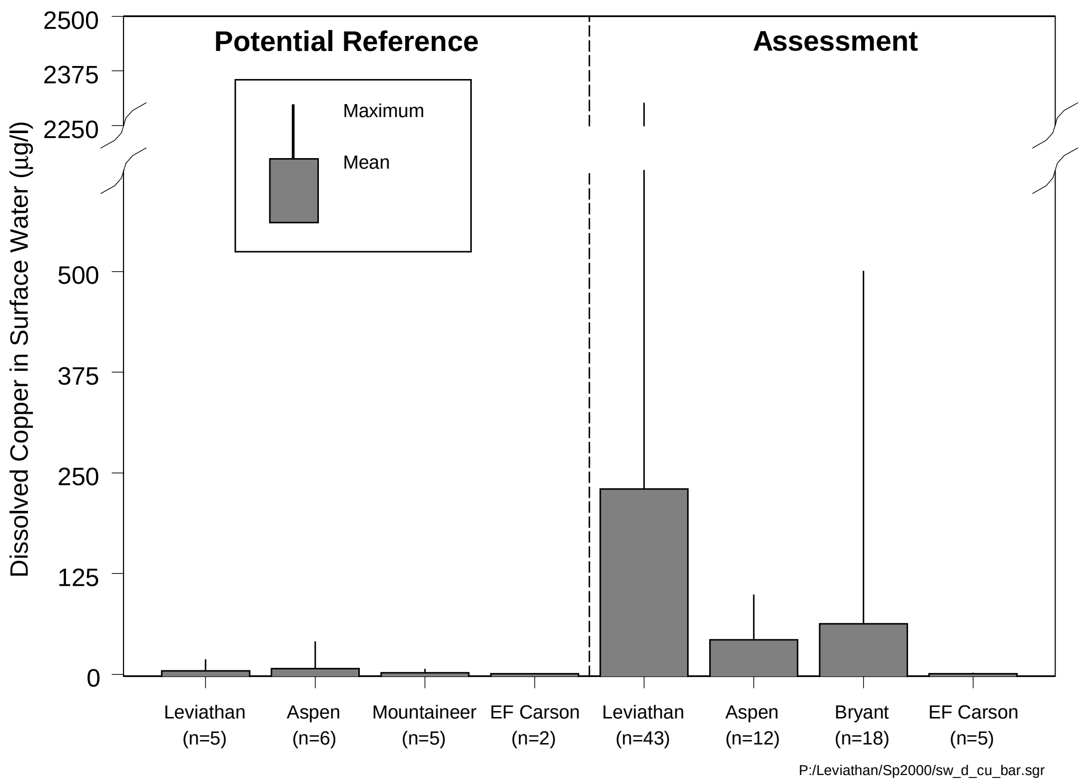

Figure 3.5. Surface water dissolved copper in potential reference and assessment reaches of Leviathan mine area. Samples reported as nondetected are plotted at one-half the analytical detection limit.

Sources: LRWQCB, 1999; Thomas and Lico, 2000; Thompson and Welsh, 2000.

Dissolved copper concentrations in the Leviathan Creek assessment reach were up to two orders of magnitude greater than those in reference sites (Figure 3.5). Dissolved copper was detected in 42 of 43 samples collected in the Leviathan Creek assessment reach compared to 7 of 18 samples collected in potential reference reaches.[3] The maximum copper concentration in the Leviathan Creek assessment reach was 2,300 µg/L, whereas the maximum concentration reported for potential reference reaches was 40 µg/L. Maximum copper concentrations were also elevated in the Aspen Creek and Bryant Creek assessment reaches compared to concentrations in potential

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3. The detection limit for dissolved copper was 1.0 µg/L in USGS and LRWQCB samples. Copper was detected in all USFWS samples, and no detection limit was presented.

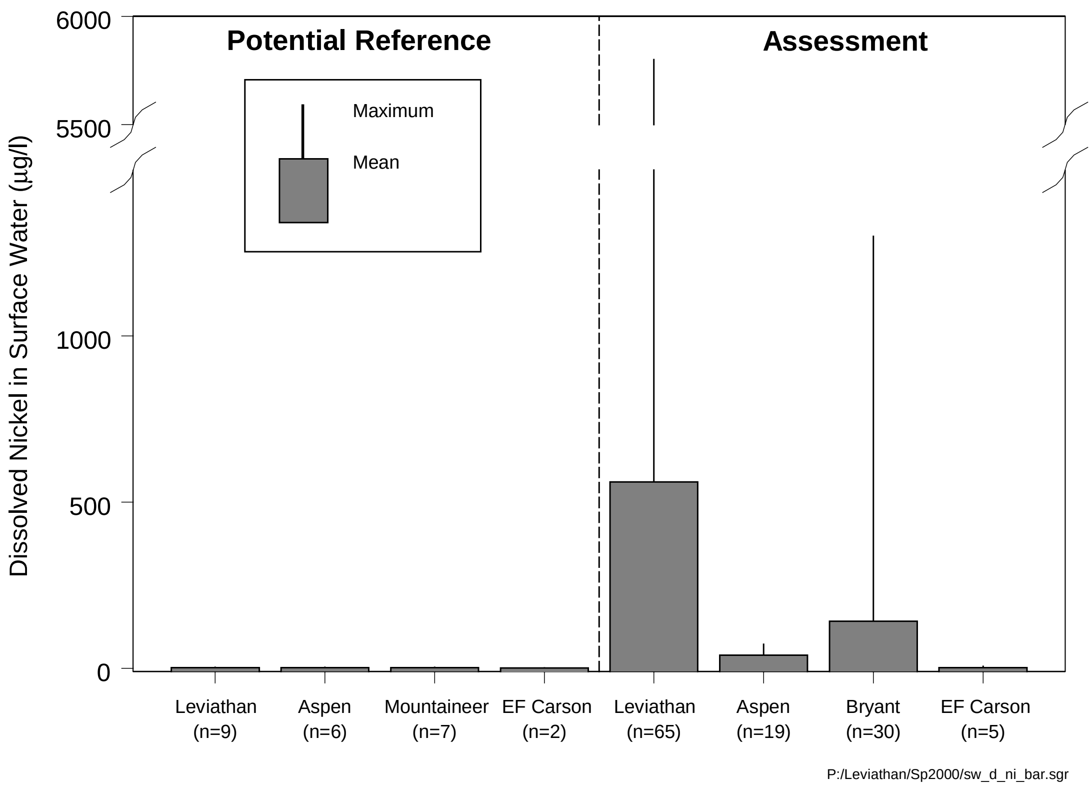

Figure 3.6. Surface water dissolved nickel in potential reference and assessment reaches of Leviathan mine area. Samples reported as nondetected are plotted at one-half the analytical detection limit.

Sources: LRWQCB, 1999; Thomas and Lico, 2000; Thompson and Welsh, 2000.

reference reaches. Two of five samples collected in the East Fork Carson River assessment area had detectable copper, but at lower concentrations than upstream.

Maximum concentrations of dissolved nickel in Leviathan Creek and Bryant Creek assessment reaches were up to three orders of magnitude greater than concentrations in potential reference reaches. Dissolved nickel was detected in 64 of 65 samples collected in the Leviathan Creek assessment reach,[4] with a maximum concentration of 5,800 µg/L (Figure 3.6). All of the 30 samples collected in the Bryant Creek assessment reach had detectable nickel, with a

4. The detection limit for dissolved nickel was 1.0 µg/L in USGS samples, and 5 µg/L in LRWQCB samples. Nickel was detected in all USFWS samples, and no detection limit was presented.

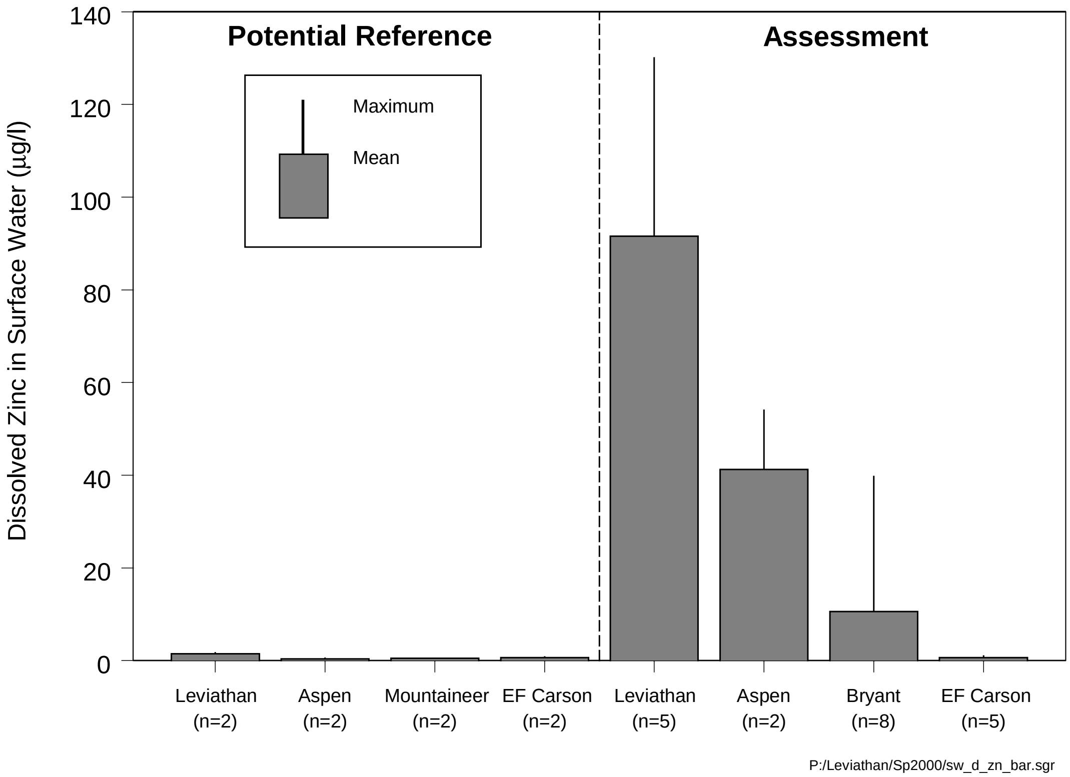

Figure 3.7. Surface water dissolved zinc in potential reference and assessment reaches of Leviathan mine area. Samples reported as nondetected are plotted at one-half the analytical detection limit.

Sources: Thomas and Lico, 2000; Thompson and Welsh, 2000.

maximum concentration of 1,300 µg/L. All of the 19 samples collected in the Aspen Creek assessment reach also had detectable nickel, with a maximum concentration of 72 µg/L. In contrast, the maximum detected nickel concentration in potential reference reaches was 0.6 µg/L, and nickel was detected in 3 of 24 samples.

As with cadmium, only samples collected by USFWS and USGS were analyzed for zinc. Zinc was detected in all samples collected in the Leviathan Creek, Aspen Creek, and Bryant Creek assessment reaches, and maximum concentrations were 130 µg/L, 54 µg/L, and 39.7 µg/L, respectively (Figure 3.7). In contrast, four of eight samples collected in potential reference reaches had detectable zinc,[5] with a maximum detected concentration of 1.7 μg/L. Although zinc was detected in two of five samples in the East Fork Carson River assessment area location, the maximum detected concentration was less than that in reference sites (1.0 μg/L).

Metal concentrations in suspended sediment were measured by the USGS in 1998 (Thomas and Lico, 2000) and the USFWS in 1999 (Thompson and Welsh, 2000). Suspended sediment concentrations can be estimated by subtracting the concentration of dissolved metals in filtered samples from the concentration of total metals in unfiltered samples.

Metal concentrations in suspended sediment were elevated in assessment reaches relative to potential reference reaches. For example, the mean total concentration of arsenic in the Leviathan Creek assessment reach was 280.6 μg/L and the mean dissolved concentration was 11.3 μg/L, indicating that the mean arsenic concentration in suspended sediment was approximately 269 μg/L (Figure 3.8). The mean arsenic concentration in suspended sediment in the Bryant Creek assessment reach was approximately 92 μg/L. In contrast, the mean arsenic concentrations in suspended sediment in the Leviathan Creek, Aspen Creek, Mountaineer Creek, and East Fork Carson River potential reference areas were approximately 8.5 μg/L, 30.3 μg/L, 9.9 μg/L, and 71.8 μg/L, respectively.

The concentrations of dissolved cadmium represented approximately 100% of the total cadmium concentration in all of the sampling reaches. Thus, the data suggest that the cadmium concentration in suspended sediment is negligible.

Although the percentage of the total copper concentration represented by suspended sediment was lower than that of arsenic, suspended copper concentrations were also more elevated in assessment reaches than in potential reference reaches (Figure 3.9). The mean copper concentration in suspended sediment was approximately 6 μg/L in the Leviathan Creek assessment reach, approximately 20 μg/L in the Aspen Creek assessment reach, and approximately 21 μg/L in the Bryant Creek assessment reach. In contrast, the mean copper concentration in suspended sediment in the Leviathan Creek, Aspen Creek, Mountaineer Creek, and East Fork Carson River potential reference areas was less than 1 μg/L.

Suspended nickel is approximately 0% of the total concentration of 343 μg/L in the Leviathan Creek assessment reach (Figure 3.10). The suspended nickel concentration in the Aspen Creek assessment reach was approximately 1 μg/L, or about 2% of the total concentration. However, the fraction of the total nickel concentration represented by suspended sediment was somewhat higher in Bryant Creek, where the concentration was approximately 12 μg/L (about 16% of the

5. The detection limit for dissolved zinc was 1.0 μg/L in USGS samples, and 0.5 μg/L in USFWS samples.

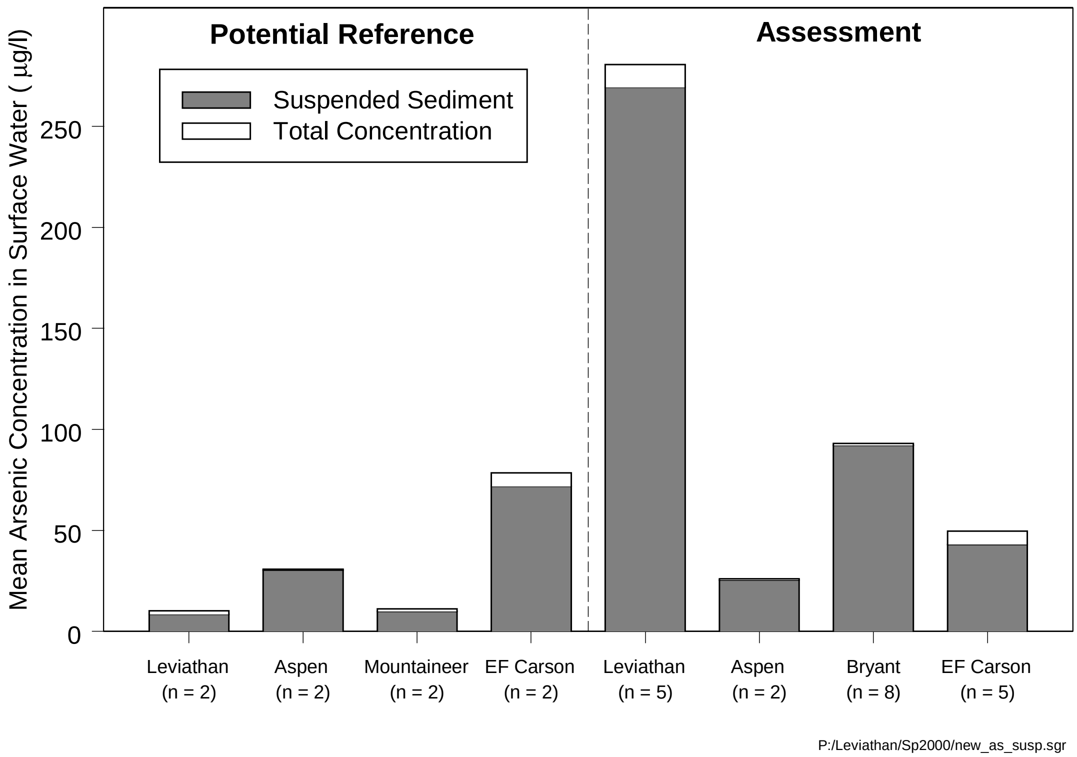

Figure 3.8. Comparison of dissolved and total arsenic in potential reference and assessment reaches of Leviathan mine area. Note that the top of the bar represents total arsenic concentration and the gray bar represents the suspended portion of that total. Thus the white portion of the bar represents the dissolved portion of the total. Samples reported as nondetected are plotted at one-half the analytical detection limit.

total). The suspended nickel concentration in all four potential reference reaches was approximately 0 µg/L.

Nearly all of the total zinc concentration in the Leviathan Creek assessment reach was in the dissolved form (Figure 3.11). However the suspended zinc concentration increased downstream to approximately 5 µg/L in the Aspen Creek assessment reach (10% of the total) and to approximately 13 µg/L in Bryant Creek (55% of the total). This increase is most likely because of the increasing pH in Aspen Creek and Bryant Creek. Dissolved zinc is present at low pH, but precipitates as pH increases. Although the total concentration in the East Fork Carson River assessment reach was lower, the suspended sediment fraction was higher at 1.28 µg/L, or 67% of

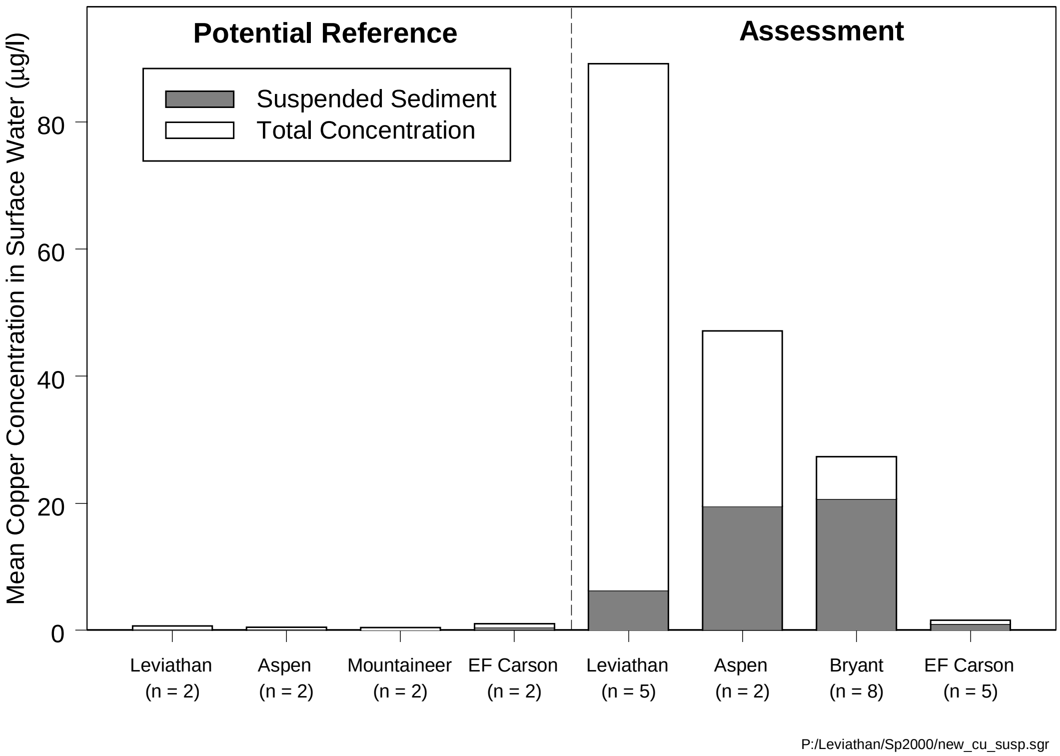

Figure 3.9. Comparison of dissolved and total copper in potential reference and assessment reaches of Leviathan mine area. Note that the top of the bar represents total copper concentration and the gray bar represents the suspended sediment portion of that total. Thus the white portion of the bar represents the dissolved sediment portion of the total. Samples reported as nondetected are plotted at one-half the analytical detection limit.

Sources: Thomas and Lico, 2000; Thompson and Welsh, 2000.

the total concentration. The suspended zinc concentrations in the reference reaches ranged from 0 μg/L to approximately 1 μg/L.

In summary, low pH and elevated metal concentrations have been measured in surface water resources downstream of the mine site. Measured pH was lower downstream of the site than upstream, and metal concentrations were higher in downstream samples than upstream reference samples. These data confirm that surface water resources have been exposed to hazardous substances, particularly in Leviathan Creek, Aspen Creek, and Bryant Creek. Moreover, the East

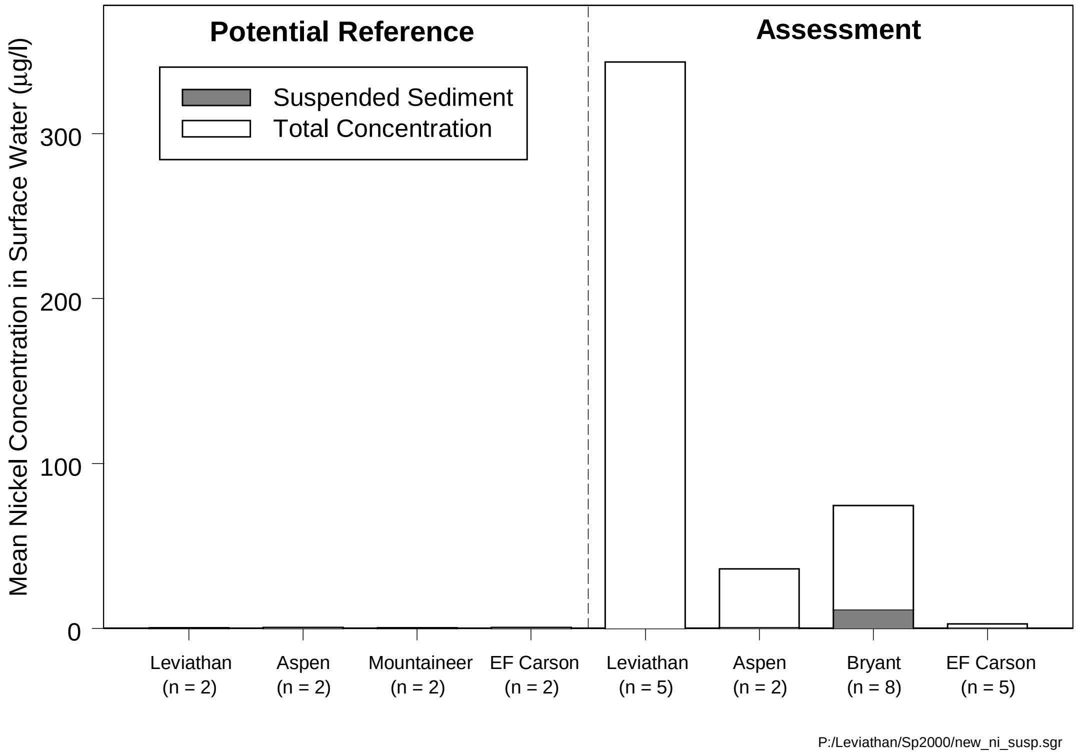

Figure 3.10. Comparison of dissolved and total nickel in potential reference and assessment reaches of Leviathan mine area. Note that the top of the bar represents total nickel concentration and the gray bar represents the suspended sediment portion of that total. Thus the white portion of the bar represents the dissolved sediment portion of the total. Samples reported as nondetected are plotted at one-half the analytical detection limit.

Sources: Thomas and Lico, 2000; Thompson and Welsh, 2000.

Fork Carson River is potentially exposed to hazardous substances entering from Bryant Creek Although this exposure is not confirmed by recent sampling, historical data on the 1959 fish kill in the East Fork Carson River indicate that, at least at some times under certain conditions, this exposure likely has occurred.

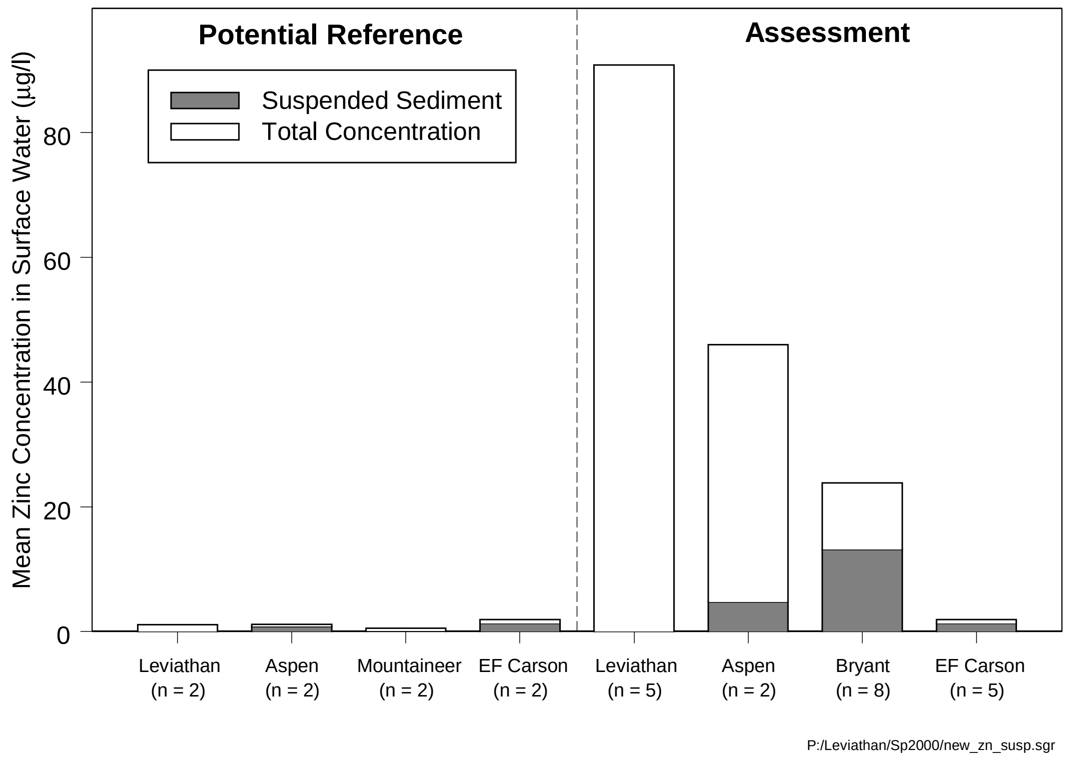

Figure 3.11. Comparison of dissolved and total zinc in potential reference and assessment reaches of Leviathan mine area. Note that the top of the bar represents total zinc concentration and the gray bar represents the suspended sediment portion of that total. Thus the white portion of the bar represents the dissolved sediment portion of the total. Samples reported as nondetected are plotted at one-half the analytical detection limit.

Sources: Thomas and Lico, 2000; Thompson and Welsh, 2000.

3.3 Sediments

Sediments are defined in the DOI regulations as a component of the surface water resource [43 CFR § 11.14 (pp)]. However, for the purposes of this assessment plan, sediments are addressed separately from surface water because specific sediment data have been collected at this site, and sediments can be an ongoing exposure pathway to other natural resources.

Bed sediment samples were collected by the USGS in September 1998 in potential reference reaches in Leviathan Creek, Aspen Creek, Mountaineer Creek, and the East Fork Carson River, and in assessment reaches in Leviathan Creek, Aspen Creek, Bryant Creek, and the East Fork Carson River (see Figure 3.1; Thomas and Lico, 2000). The samples were composites of five subsamples collected from the top 1 inch of sediment in depositional areas and were sieved to retain only sediments less than 63 μm in diameter for analysis.

Concentrations of hazardous substances were generally elevated in assessment reaches compared to reference reaches (Figures 3.12 to 3.16), although the reach in which they were most elevated varied among metals. The maximum arsenic concentration in sediment was 680 μg/g in the Leviathan Creek assessment reach and 230 μg/g in the Bryant Creek assessment reach, whereas the maximum concentration in any potential reference reach was 25 μg/g (Figure 3.12). Only three samples were analyzed from the Aspen Creek assessment reach, where the maximum concentration was 55 μg/g, slightly elevated compared to the potential reference reaches. The maximum concentration in the East Fork Carson River assessment reach was 21 μg/g, similar to the potential reference reaches.

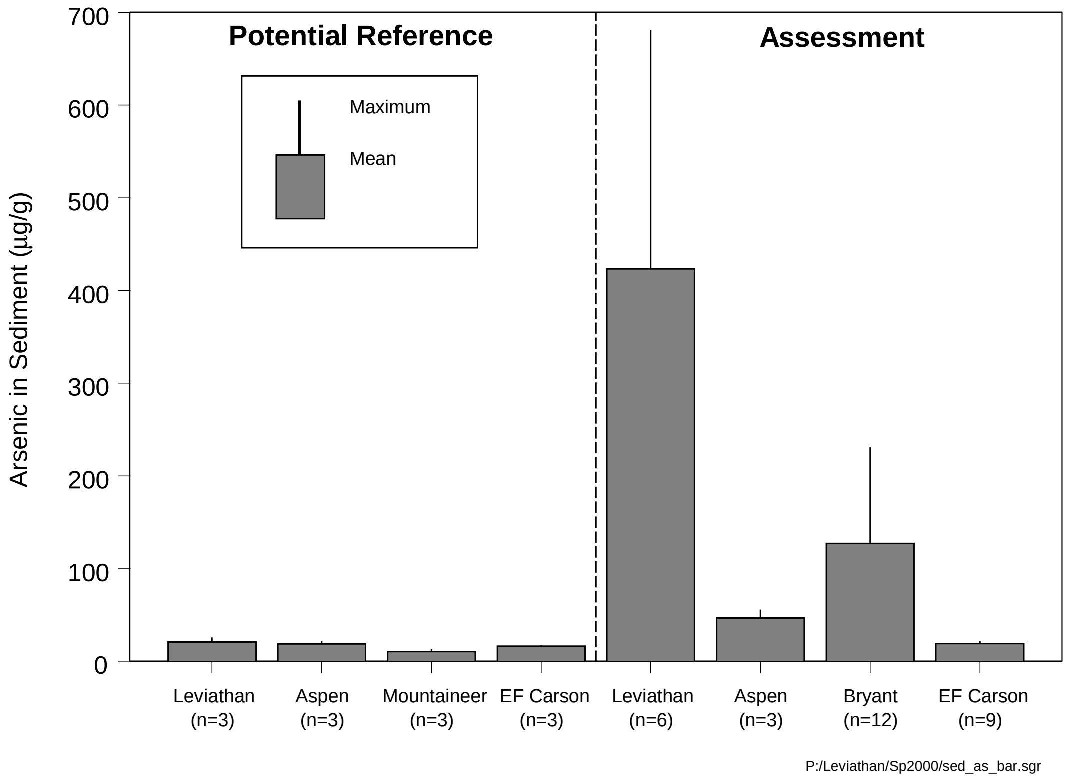

Figure 3.12. Arsenic concentrations of sediment in potential reference and assessment reaches of Leviathan mine area.

Source: Thomas and Lico, 2000.

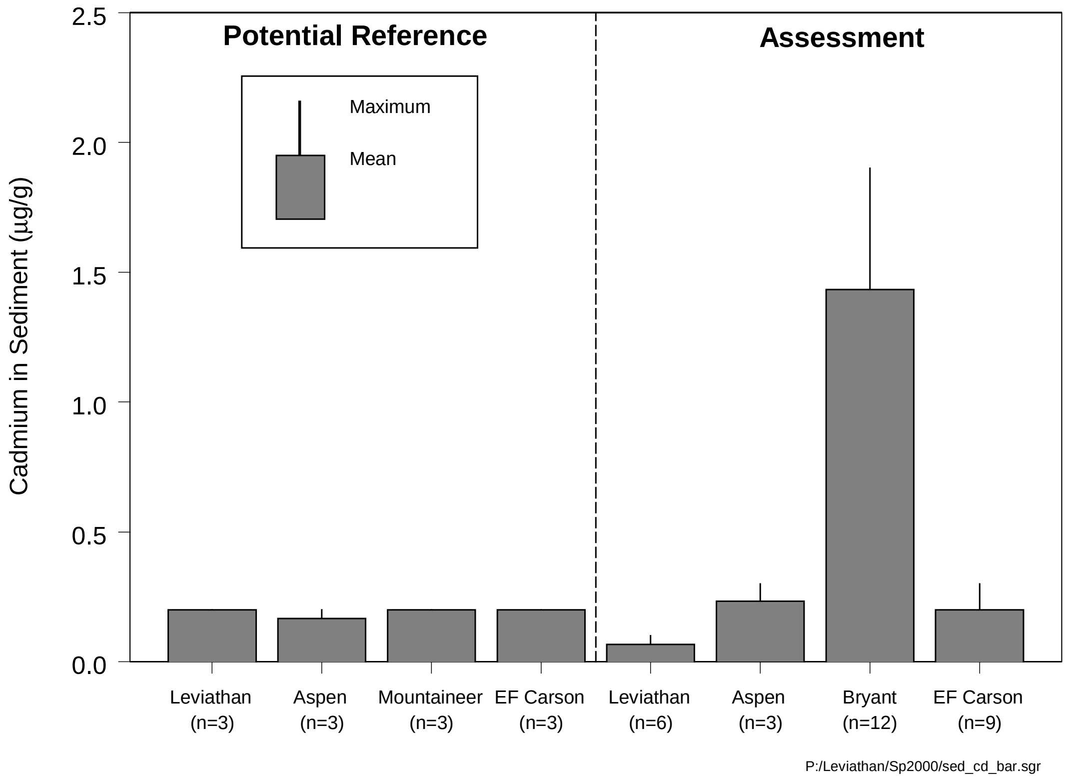

Figure 3.13. Cadmium concentrations of sediment in potential reference and assessment reaches of Leviathan mine area. Samples reported as nondetected are plotted at one-half the analytical detection limit.

Source: Thomas and Lico, 2000.

Cadmium was also elevated in sediments in assessment reaches compared to potential reference reaches; however, it followed a different pattern (Figure 3.13). The most elevated concentration of cadmium in sediment was measured in the Bryant Creek assessment reach (1.9 µg/g). The maximum concentration of cadmium in sediment was 0.3 µg/g in the Aspen Creek and East Fork Carson River assessment reaches, whereas the maximum concentration was 0.2 µg/g in the potential reference reaches. The maximum concentration of cadmium in sediment in the Leviathan Creek assessment reach was 0.1 µg/g.

Concentrations of copper in sediment also followed a different pattern than arsenic or cadmium (Figure 3.14). The highest concentration, 400 µg/g, was measured in the Aspen Creek assessment reach. Maximum concentrations in the Bryant Creek and Leviathan Creek assessment

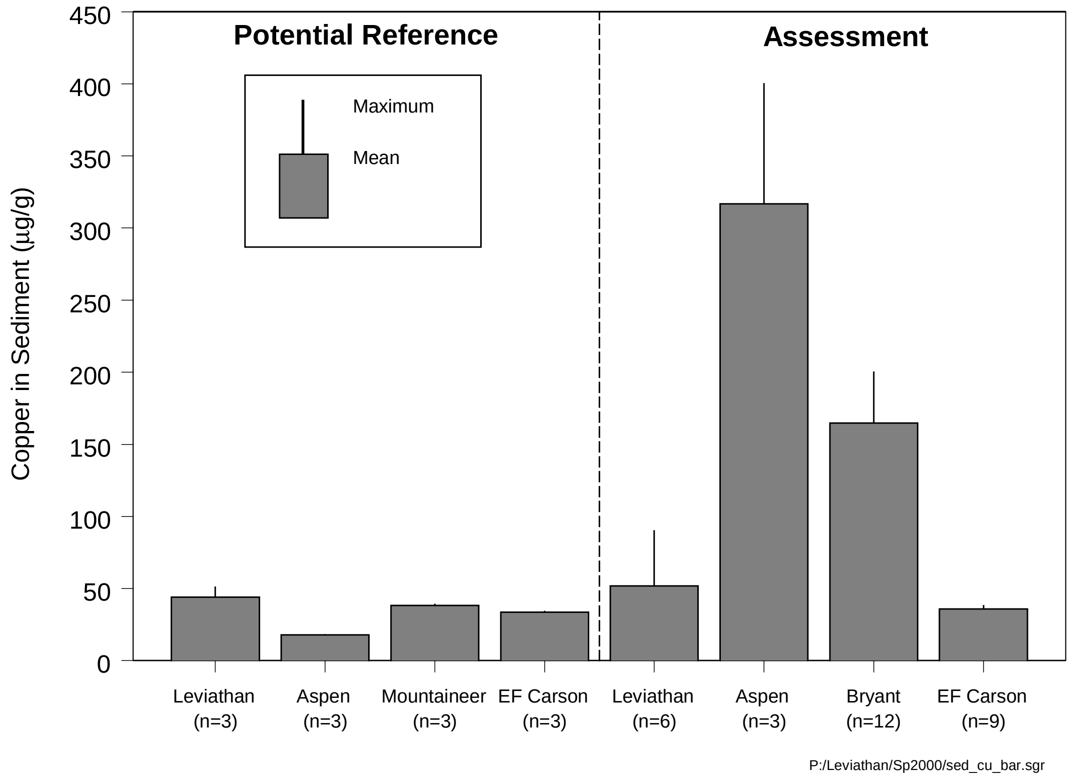

Figure 3.14. Copper concentrations of sediment in potential reference and assessment reaches of Leviathan mine area.

Source: Thomas and Lico, 2000.

reaches were also elevated, at 200 µg/g and 90 µg/g, respectively. In contrast, the maximum concentration measured in potential reference reaches was 51 µg/g. The maximum concentration of copper in the East Fork Carson River assessment reach was 38 µg/g, comparable to potential reference reaches.

Concentrations of nickel in sediment followed a similar pattern as concentrations of cadmium. The maximum nickel concentration in sediment of 390 µg/g was measured in the Bryant Creek assessment reach (Figure 3.15). Other assessment reaches were not elevated compared to the potential reference reaches, where the maximum nickel concentration was 41 µg/g.

The maximum concentration of zinc in sediment was measured in the Bryant Creek assessment reach (290 µg/g) (Figure 3.16). Zinc concentration was also elevated in the Aspen Creek assessment reach compared to potential reference reaches, where the maximum concentrations

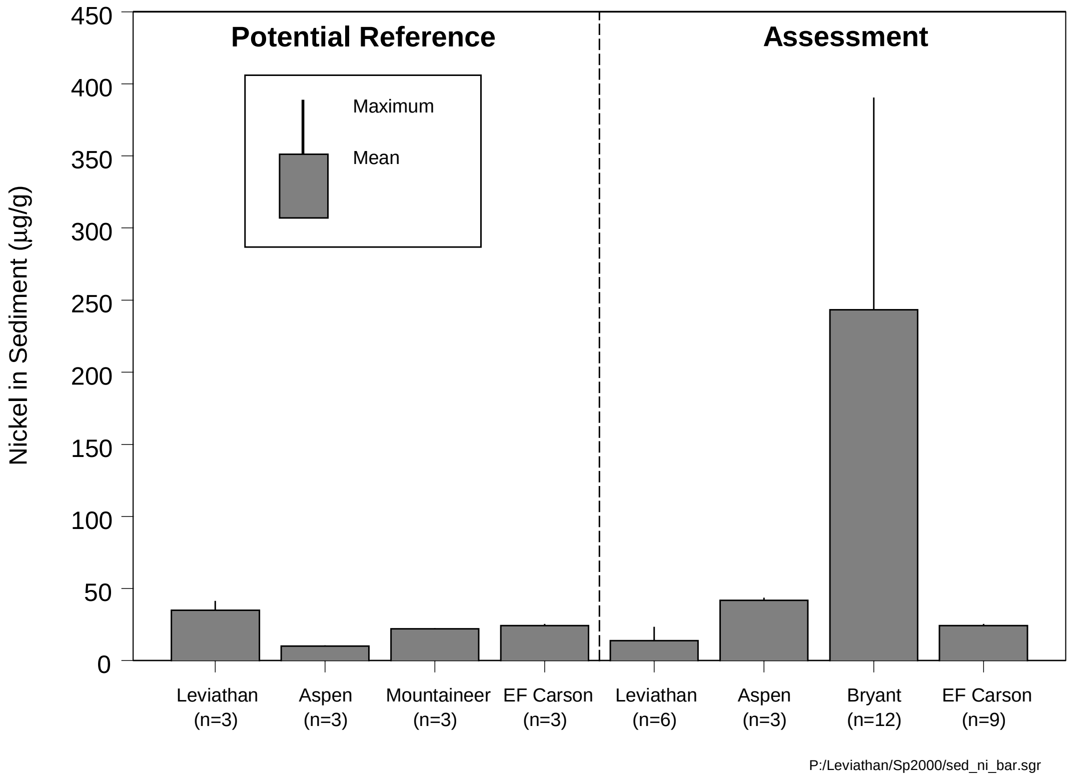

Figure 3.15. Nickel concentrations of sediment in potential reference and assessment reaches of Leviathan mine area.

Source: Thomas and Lico, 2000.

were 150 µg/g and 100 µg/g, respectively. Concentrations of zinc in sediment were not elevated in the Leviathan Creek and East Fork Carson River assessment reaches compared to potential reference reaches.

The patterns in sediment metal concentrations appear to be related to the pH of surface water. Arsenic concentrations in sediment were highest in Leviathan Creek (Figure 3.12), because arsenic precipitates out of surface water when pH increases due to dilution by less acidic water, at a relatively low pH. Arsenic was lower in downstream reaches in both surface water (Figure 3.3) and sediment (Figure 3.12) because of this precipitation process. Concentrations of cadmium, copper, nickel, and zinc in sediment were higher in Bryant Creek than in Leviathan Creek because these metals precipitate from surface water at higher pH levels than those observed in Leviathan Creek. As pH increases further with dilution in Bryant Creek, these metals precipitate out of the water and are deposited as bed sediments.

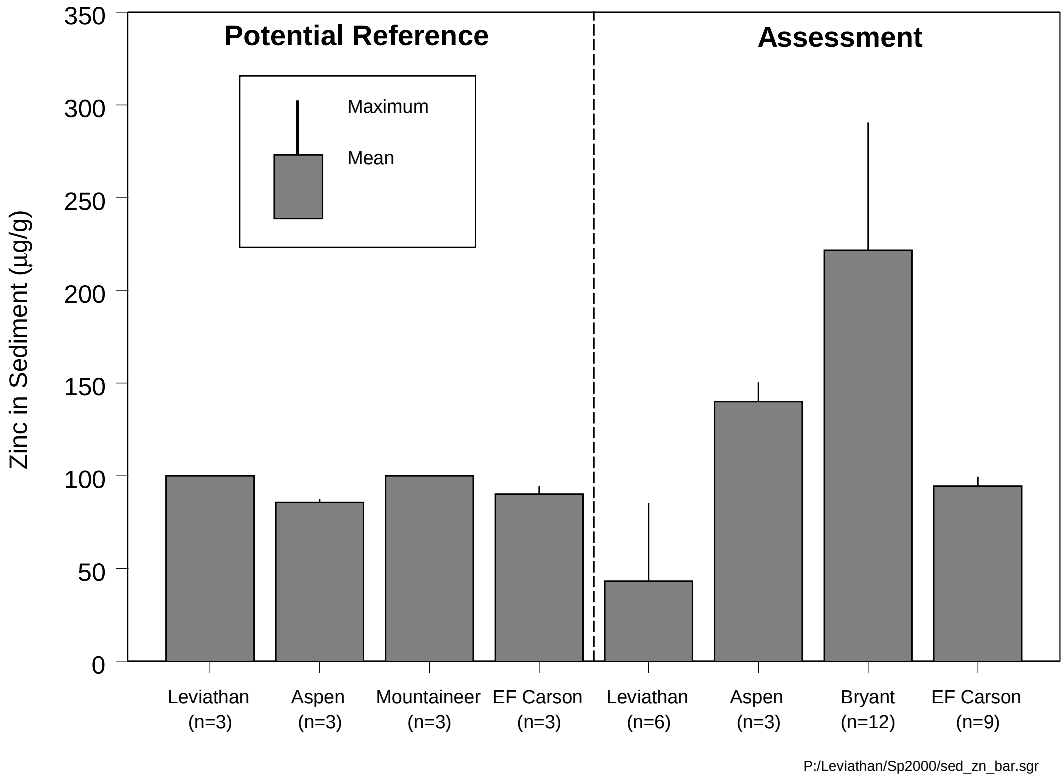

Figure 3.16. Zinc concentrations of sediment in potential reference and assessment reaches of Leviathan mine area.

Source: Thomas and Lico, 2000.

In summary, elevated metal concentrations have been measured in sediment downstream of the mine site. Metal concentrations were elevated in downstream samples compared to upstream samples from potential reference reaches, and the pattern of sediment metal concentrations was controlled by the pH of surface water. These data confirm that sediment resources have been exposed to hazardous substances.

3.4 Groundwater Resources

Groundwater is defined in the DOI regulations as “water in a saturated zone or stratum beneath the surface of land or water and the rocks and sediment through which ground water moves” [43 CFR § 11.14(t)].

Groundwater was sampled by SRK Consulting in 1998 in wells drilled at the mine site (see Figure 4.16; SRK Consulting, 1999). Wells were located in the Leviathan Creek drainage and ranged in depth from 18 to 151 ft.

Metal concentrations in groundwater ranged from below detection to concentrations as high as or higher than those found in surface water in the Leviathan Creek assessment reach (Table 3.1). Maximum concentrations of metals such as arsenic, cadmium, copper, nickel, and zinc were several orders of magnitude greater than minimum concentrations. The minimum pH measured was 1.88. Metal concentrations were highest and pH was lowest in wells near the open pit and treatment ponds. Metal concentrations tended to be lower in wells located near the periphery of the mine site.

Table 3.1. Groundwater quality summary of samples from wells at Leviathan mine site.

	October 12-16, 1998 (n = 13)			November 2-6, 1998 (n = 14)		
Parameter	**Min**	**Median**	**Max**	**Min**	**Median**	**Max**
Arsenic (µg/L)	0.5 (U)[a]	28.2	6,640	1.1	21.7	6,520
Cadmium (µg/L)	1.1 (U)	1.1	169	1.1 (U)	1.65	166
Copper (µg/L)	0.55 (U)	2.9	8,490	0.55 (U)	4.05	9,300
Nickel (µg/L)	7.55 (U)	792	9,620	7.55 (U)	194.3	10,500
Zinc (µg/L)	3.9	310	2,140	6.2	152	2,190
pH	2.22	4.25	7.11	1.88	4.355	7.15

a. U = not detected. Value shown is one-half reported detection limit. Median is calculated using one-half reported detection limit for samples where parameter is not detected.

Source: SRK Consulting, 1999.

In conclusion, groundwater samples from wells at the mine site contained elevated concentrations of hazardous substances. Metal concentrations in wells on site were several orders of magnitude greater than those measured in wells on the periphery of the mine site. These data confirm that groundwater at the mine site has been exposed to hazardous substances.

3.5 Biological Resources

Biological resources are defined in the DOI regulations as “those natural resources referred to in section 101(16) of CERCLA as fish and wildlife and other biota. Fish and wildlife include marine and freshwater aquatic and terrestrial species; game, nongame, and commercial species;

and threatened, endangered, and State sensitive species. Other biota encompass shellfish, terrestrial and aquatic plants, and other living organisms" [43 CFR § 11.14(s)].

Exposure of biological resources to hazardous substances can be confirmed by evaluating other media to which they are exposed [43 CFR § 11.62(b)(1)(v); § 11.62(e)(11)]. Aquatic invertebrates, fish, aquatic and riparian vegetation, and terrestrial wildlife can be exposed to hazardous substances through surface water and sediment pathways. For example, aquatic invertebrates such as mayflies live in the bottom sediments of streams and consume algae, bacteria, and fine detrital material from the substrate. They are thus exposed to hazardous substances in surface water and sediment through direct contact and consumption. Thus, exposure of biological resources downstream of the mine site is confirmed through exposure of surface water resources (Section 3.2) and sediment (Section 3.3).

In addition, exposure of biological resources to hazardous substances can be confirmed through measurement of hazardous substances in biota [43 CFR § 11.62(f)(1)(i)]. Specific data confirming the exposure of biological resources to hazardous substances released from the mine are available for aquatic invertebrates and fish. No specific data are currently available to confirm exposure of riparian vegetation and terrestrial wildlife resources.

3.5.1 Aquatic invertebrate tissue sampling

In September 1998, the USFWS sampled aquatic insects from reference locations and locations downstream of the mine (Thompson and Welsh, 1999). Samples were collected by disturbing the bottom of the stream and catching aquatic insects in a kick net. Caddisflies (Family Hydropsychidae) and mayflies (Family Baetidae) were collected in composite samples and analyzed for concentrations of metals. Samples were collected in potential reference reaches in Leviathan Creek, Aspen Creek, Mountaineer Creek, and the East Fork Carson River (see Figure 3.1). Assessment reaches sampled included Bryant Creek and the East Fork Carson River downstream of Bryant Creek. No samples were collected in Leviathan Creek and Aspen Creek downstream of the mine site because of the absence or near absence of caddisflies and mayflies in these reaches. All concentrations were reported in dry weights as parts per million (ppm).

Results indicate that aquatic invertebrates have been exposed to metals in the Bryant Creek assessment reach (Figures 3.17 to 3.21). Concentrations of most metals were approximately one order of magnitude more elevated in Bryant Creek than in reference locations. In addition, concentrations of some metals were more elevated in mayflies in the East Fork Carson River than in reference locations. For example, the maximum arsenic concentration in caddisflies in the Bryant Creek assessment reach was 9.8 ppm, compared to 5.77 ppm in potential reference reaches (Figure 3.17). The maximum arsenic concentration in mayflies in the Bryant Creek assessment reach was 41.5 ppm, compared to 5.5 ppm in potential reference reaches. Arsenic

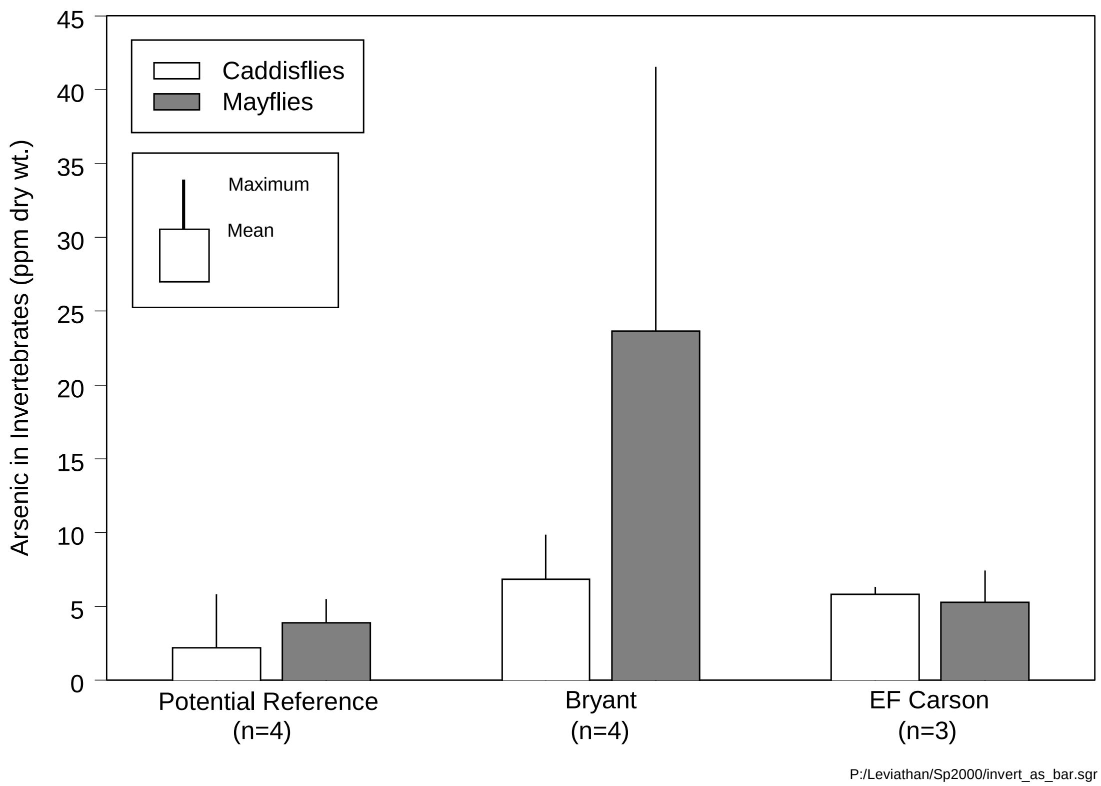

Figure 3.17. Arsenic concentrations in caddisflies (Family Hydropsychidae) and mayflies (Family Baetidae) collected in potential reference reaches of Leviathan mine area, the Bryant Creek assessment reach, and the East Fork Carson River assessment reach.

Source: Thompson and Welsh, 1999.

concentrations in caddisflies and mayflies were slightly elevated in the East Fork Carson River assessment reach compared to potential reference reaches.

Cadmium concentrations in both caddisflies and mayflies were elevated in the Bryant Creek and East Fork Carson River assessment reaches compared to potential reference reaches (Figure 3.18). The maximum cadmium concentrations in caddisflies and mayflies in the Bryant Creek assessment reach were 2.5 ppm and 10.6 ppm, respectively. The maximum concentrations in caddisflies and mayflies in the East Fork Carson River assessment reach were slightly lower, at 0.6 ppm and 5.8 ppm, respectively. In contrast, the maximum concentrations observed in potential reference reaches were 0.4 ppm in caddisflies and 0.55 ppm in mayflies.

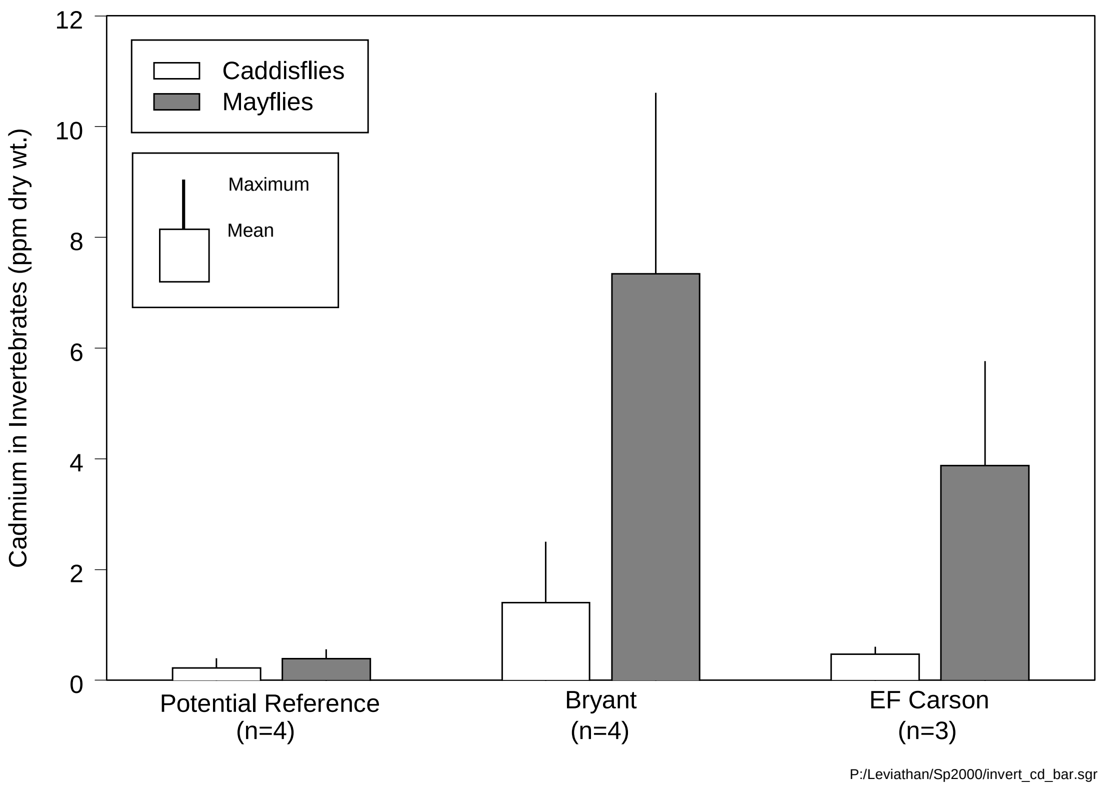

Figure 3.18. Cadmium concentrations in caddisflies (Family Hydropsychidae) and mayflies (Family Baetidae) collected in potential reference reaches of Leviathan mine area, the Bryant Creek assessment reach, and the East Fork Carson River assessment reach.

Source: Thompson and Welsh, 1999.

Copper concentrations in invertebrates were elevated in the Bryant Creek assessment reach (Figure 3.19). In the Bryant Creek assessment reach, the maximum measured copper concentration was 91.8 ppm in caddisflies, and 118 ppm in mayflies. In potential reference reaches, the maximum copper concentration was much lower, at 24.7 ppm in caddisflies and 20.3 ppm in mayflies. The maximum copper concentration in caddisflies in the East Fork Carson River assessment reach was lower than that in potential reference sites (18 ppm) and the maximum concentration in mayflies was slightly higher (27.6 ppm).

Nickel concentrations in aquatic invertebrates in the Bryant Creek assessment reach were elevated compared to potential reference reaches (Figure 3.20). In the Bryant Creek assessment reach the maximum nickel concentration was 132 ppm in caddisflies and 124 ppm in mayflies. In comparison, in potential reference reaches the maximum nickel concentration was 5.6 ppm in

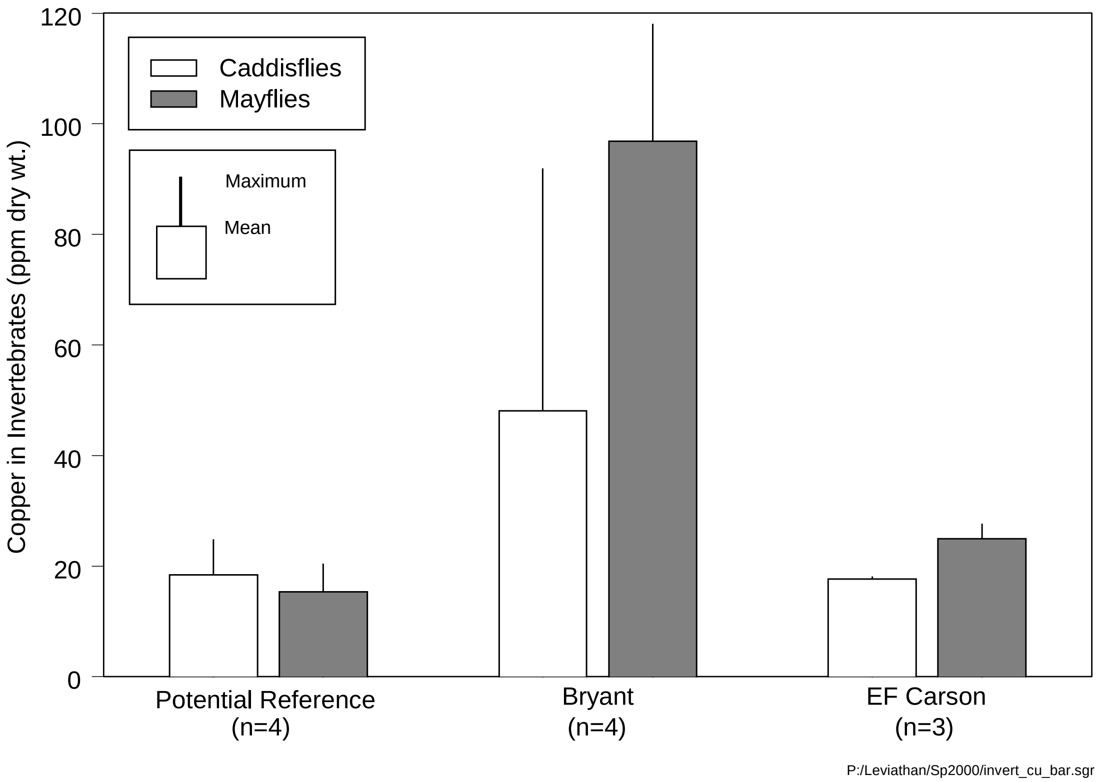

Figure 3.19. Copper concentrations in caddisflies (Family Hydropsychidae) and mayflies (Family Baetidae) collected in potential reference reaches of Leviathan mine area, the Bryant Creek assessment reach, and the East Fork Carson River assessment reach.

Source: Thompson and Welsh, 1999.

both caddisflies and mayflies. The maximum concentrations measured in caddisflies and mayflies in the East Fork Carson River assessment reach were slightly more elevated than those in potential reference reaches, at 7.2 ppm and 6.1 ppm, respectively.

Zinc concentrations in aquatic invertebrates were also elevated in the Bryant Creek assessment reach, where the maximum concentration was 235 ppm in caddisflies and 830 ppm in mayflies (Figure 3.21). In contrast, the maximum concentration measured in potential reference reaches was 172 ppm in caddisflies and 211 ppm in mayflies. Maximum zinc concentrations in aquatic invertebrates in the East Fork Carson River assessment reach were lower than those measured in potential reference reaches.

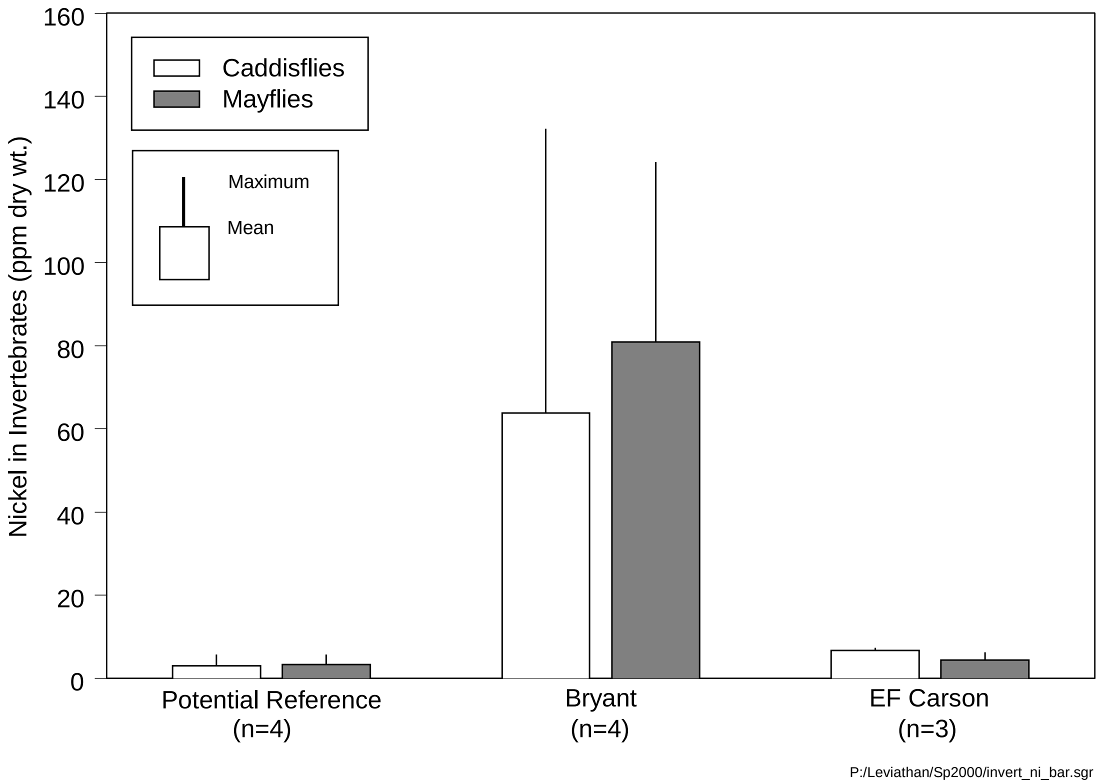

Figure 3.20. Nickel concentrations in caddisflies (Family Hydropsychidae) and mayflies (Family Baetidae) collected in potential reference reaches of Leviathan mine area, the Bryant Creek assessment reach, and the East Fork Carson River assessment reach.

Source: Thompson and Welsh, 1999.

In summary, invertebrates downstream of the mine site have been exposed to hazardous substances through their contact with exposed surface water and sediment resources. In addition, elevated metal concentrations have been measured in invertebrates downstream of the mine site. Concentrations were highest in the Bryant Creek assessment reach, but were elevated for some hazardous substances in the East Fork Carson River assessment reach compared to potential reference reaches. Concentrations were generally higher in mayflies than in caddisflies, which is most likely a result of different life history parameters such as stage duration or timing of emergence.

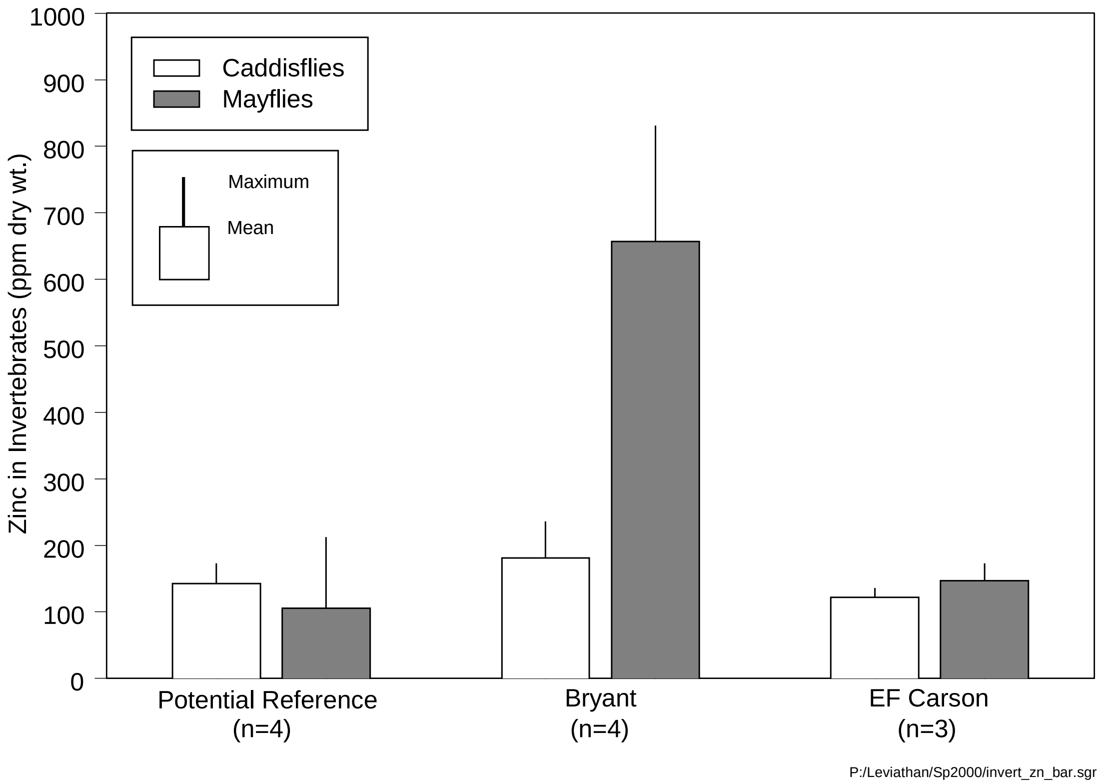

Figure 3.21. Zinc concentrations in caddisflies (Family Hydropsychidae) and mayflies (Family Baetidae) collected in potential reference reaches of Leviathan mine area, the Bryant Creek assessment reach, and the East Fork Carson River assessment reach.

Source: Thompson and Welsh, 1999.

3.5.2 Fish tissue sampling

In October 1998, the USFWS collected fish in the East Fork Carson River for analysis of accumulated metal concentrations (Thompson and Welsh, 1999). Samples were collected upstream of Bryant Creek (a potential reference reach), downstream of Bryant Creek, and just downstream of the former Ruhenstroth Dam near Dresslerville, Nevada (see Figure 3.1). Fish were not collected in Bryant Creek or other assessment reaches closer to the mine because surveys indicated that few or no fish were present in these reaches (Lehr, 2000). Mountain whitefish (*Prosopium williamsoni*) were selected for analysis because they are present at all three sampling locations, primarily consume aquatic invertebrates, and are a food source for humans and wildlife (Thompson and Welsh, 1999). All concentrations were reported as wet weights in parts per million (ppm).

The results indicate that concentrations of several metals were elevated in fish tissue downstream of Bryant Creek relative to upstream of Bryant Creek (Figures 3.22 to 3.25). Concentrations of cadmium, copper, nickel, and zinc were approximately two to six times higher in some downstream samples.

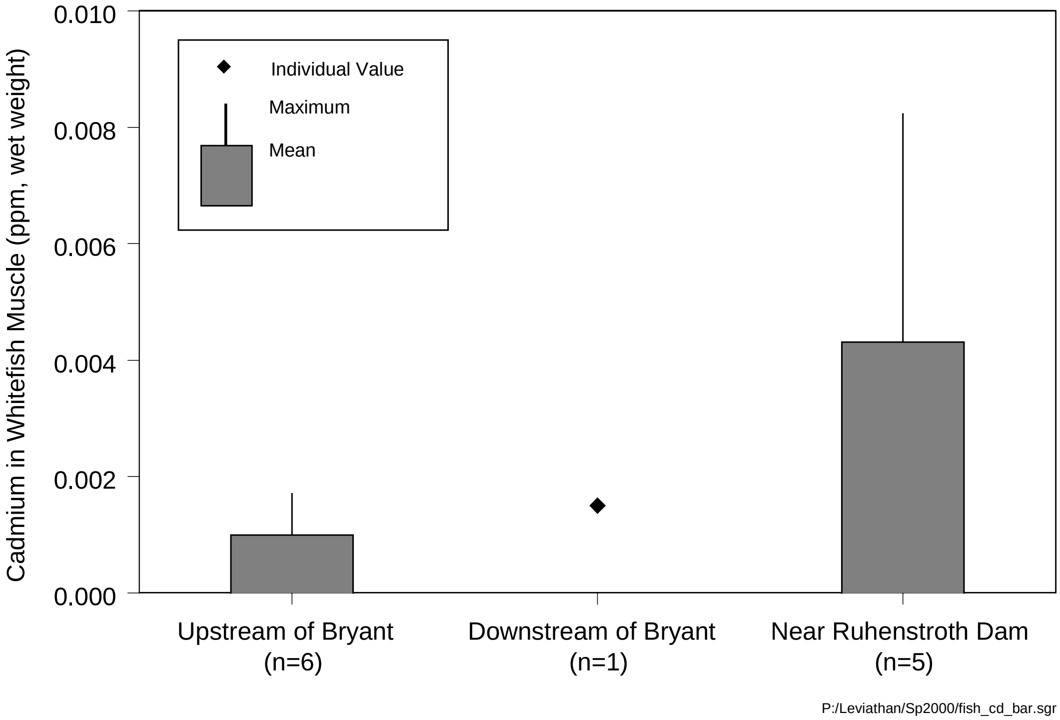

Figure 3.22. Cadmium concentrations in mountain whitefish (*Prosopium williamsoni*) muscle collected in the East Fork Carson River.

Source: Thompson and Welsh, 1999.

For example, cadmium was detected in all of the five whitefish muscle samples collected near Ruhenstroth Dam (Figure 3.22). The maximum concentration of cadmium in tissue was 0.008 ppm, and the mean was 0.004 ppm. Upstream of Bryant Creek, cadmium was detected in three of the six samples collected, and the maximum detected concentration was 0.002 ppm. The concentration of cadmium in the one sample collected just downstream of Bryant Creek was 0.002 ppm.

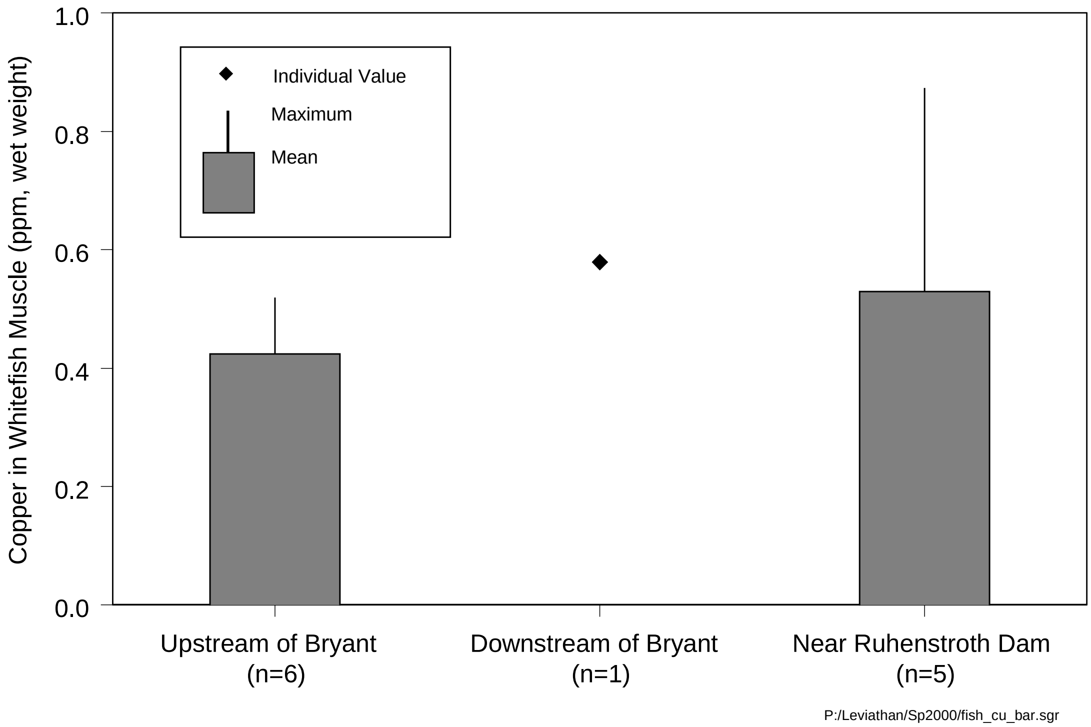

Figure 3.23. Copper concentrations in mountain whitefish (*Prosopium williamsoni*) muscle collected in the East Fork Carson River.

Source: Thompson and Welsh, 1999.

Copper was also somewhat elevated in whitefish muscle in samples collected near the former Ruhenstroth Dam, where the maximum concentration was 0.87 ppm and the mean was 0.53 ppm (Figure 3.23). In contrast, the maximum measured concentration upstream of Bryant Creek was 0.52 ppm and the mean was 0.42 ppm. The concentration of copper in the one sample collected just downstream of Bryant Creek was 0.58 ppm, slightly more elevated than the maximum concentration at the potential reference site.

The maximum concentration of nickel in whitefish tissue collected near Ruhenstroth Dam was 0.06 ppm, several times higher than the maximum concentration measured upstream of Bryant Creek, 0.01 ppm (Figure 3.24). Nickel was detected in one of the six samples collected upstream of Bryant Creek, whereas it was detected in four of the five samples collected near Ruhenstroth Dam. The one sample collected just downstream of Bryant Creek had a nickel concentration of 0.01 ppm.

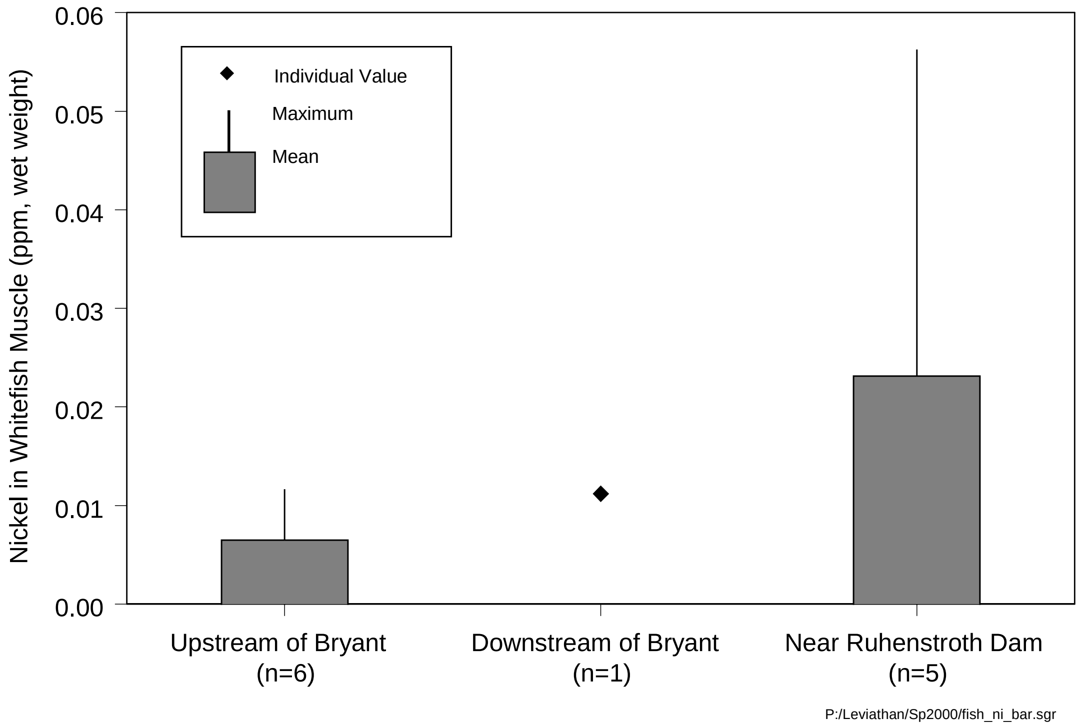

Figure 3.24. Nickel concentrations in mountain whitefish (*Prosopium williamsoni*) muscle collected in the East Fork Carson River.

Source: Thompson and Welsh, 1999.

Zinc was detected in all of the whitefish muscle samples collected in the East Fork Carson River (Figure 3.25). The maximum zinc concentration was slightly elevated near Ruhenstroth Dam (4.27 ppm) relative to that upstream of Bryant Creek (3.35 ppm). The mean concentration near Ruhenstroth Dam was 3.45 ppm, whereas the mean concentration upstream of Bryant Creek was 2.96. The zinc concentration in the one sample collected just downstream of Bryant Creek was 3.80, higher than the maximum measured concentration at the potential reference site upstream of Bryant Creek.

In summary, the data suggest that whitefish downstream of the mine site have been exposed to hazardous substances through their contact with exposed surface water and sediment resources.

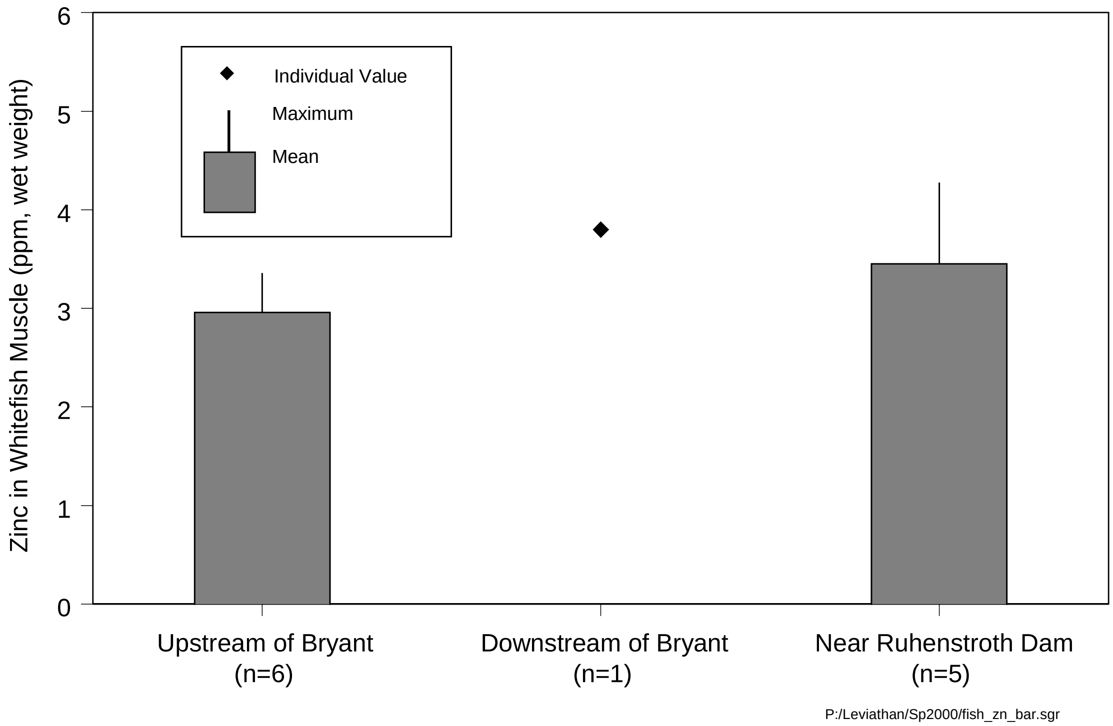

Figure 3.25. Zinc concentrations in mountain whitefish (*Prosopium williamsoni*) muscle collected in the East Fork Carson River.

Source: Thompson and Welsh, 1999.

3.5.3 Exposure of biological resources

Biological resources have been exposed to hazardous substances released from the mine. Exposure of aquatic invertebrates, fish, aquatic and riparian vegetation, and terrestrial wildlife to hazardous substances downstream of the mine site is confirmed through their contact with surface water and sediment that has been exposed to hazardous substances.

In addition, elevated metal concentrations have been measured in biological resources, including benthic invertebrates and fish, downstream of the mine site. These data support the conclusion that biota are exposed to hazardous substances.

3.6 Conclusions

The available data confirm that natural resources have been exposed to metals and/or low pH downstream of the mine (Table 3.2). Exposure of surface water and sediment as far downstream as Bryant Creek was confirmed with available data. Insufficient data were available to confirm exposure in the East Fork Carson River directly; however, the confirmation of exposure of biota in this reach implies that surface water and sediment media pathways have also been exposed. Groundwater has been exposed to hazardous substances in the Leviathan Creek drainage. No data currently exist to confirm groundwater exposure in other locations. Biota, including aquatic invertebrates, fish, aquatic and riparian vegetation, and terrestrial wildlife, have been exposed to hazardous substances in surface water and sediment at least as far downstream as Bryant Creek. Specific data for aquatic invertebrates and fish suggest that biotic exposure extends into the East Fork Carson River as well.

Table 3.2. Summary of confirmed exposure of surface water, groundwater, and biota resources to hazardous substances in the Leviathan mine site area.

	Surface water				Biota		
Reach	Water	Suspended sediment	Sediment	Groundwater	Aquatic invertebrates	Fish	Other biota
Leviathan Creek	✓	✓	✓	✓	✓	✓	✓[a]
Aspen Creek	✓	✓	✓	**?**	✓	✓	✓[a]
Bryant Creek	✓	✓	✓	**?**	✓	✓	✓[a]
E.F. Carson River	*[b]	*[b]	*[b]	**?**	✓	✓	*[a, b]

a. Exposure of biota other than aquatic invertebrates and fish is confirmed by exposure of media, which they come into contact with either via direct exposure or consumption.
b. Surface water and sediment in the East Fork Carson River have not been sampled during all conditions and there are few samples to evaluate exposure fully at this time. However, the confirmed exposure of aquatic invertebrates and fish to hazardous substances in the East Fork Carson River supports the conclusion that exposure pathways such as surface water and sediment, and in turn other biota, are also exposed.

While specific hazardous substances and exposure media are discussed here, this does not imply that other exposure media are not exposed as well. For example, soil may also have been exposed to hazardous substances at this site. In addition, more extensive research may reveal more specific species of aquatic and riparian biota that have been exposed in the assessment area. Exposure of abiotic and biotic natural resources within the assessment area has been reported since the 1950s (Trustees for the Leviathan Mine Site, 1998) and continues into the present.

4. Injury Assessment Approaches

4.1 Introduction

Chapter 3 provided data confirming that natural resources in the assessment area have been exposed to multiple hazardous substances, including but not limited to arsenic, cadmium, copper, nickel, zinc, and acidity. Natural resources, including surface water, sediments, groundwater, floodplain soils, riparian vegetation, and terrestrial wildlife resources, may be injured as a result of this exposure. To determine the nature and extent of these injuries, the Trustees will conduct an injury assessment. Generally, the purpose of the injury assessment is to determine whether natural resources have been injured [43 CFR § 11.61], to identify the environmental pathways through which injured resources have been exposed to hazardous substances [43 CFR § 11.63], and to quantify the degree and extent (spatial and temporal) of injury [43 CFR § 11.71].

Department of Interior (DOI) regulations define "injury" as a:

> . . . measurable adverse change, either long- or short-term, in the chemical or physical quality or the viability of a natural resource resulting either directly or indirectly from exposure to a . . . release of a hazardous substance, or exposure to a product of reactions resulting from the . . . release of a hazardous substance. As used in this part, injury encompasses the phrases "injury," "destruction," or "loss" [43 CFR § 11.14(v)].

This chapter provides an overview of potential injuries to natural resources that will be assessed by the Leviathan Mine Council and describes the approaches that will be used to assess those injuries. Chapter 5 describes a proposed study for quantifying injury to resources that provide Tribal-specific services.

4.2 Injury Assessment Process

An injury assessment consists of two main components: injury determination and injury quantification.

1. **Injury determination.** The Trustees will determine whether an injury to one or more natural resources has occurred as a result of releases of hazardous substances [43 CFR § 11.62]. This determination will include the following two steps:

a. **Determination that injury has occurred.** In this first step, the Trustees will evaluate whether injuries that meet the definitions of injury in 43 CFR § 11.62 for surface water, groundwater, air, geologic, and biological resources have occurred. Since assessment procedures set in 40 CFR § 11 are not mandatory, the Trustees may consider other injuries not explicitly identified in the DOI regulations.

b. **Pathway determination.** The Trustees will evaluate data to identify exposure pathways by which hazardous substances are transported in the environment and natural resources are exposed to those substances [43 CFR § 11.63].

2. **Injury quantification.** The injuries determined by the Trustees will be quantified in terms of changes from "baseline conditions"[1] [43 CFR § 11.71(b) (2)]. Quantification will address the spatial and temporal extent of injury as well as the degree of injury. Quantification will be conducted primarily to provide information that is relevant to restoration and compensation.

The Trustees will emphasize the use of existing data — whenever relevant data are available — in their injury assessment. Therefore, to ensure that existing data are incorporated into the assessment, the Trustees propose to adopt a phased injury assessment approach. This approach, summarized in Figure 4.1, includes the following phases:

- **Phase I: Data compilation and critical review.** Existing historical and current site-specific baseline and assessment area data will be compiled into electronic databases for critical evaluation. In addition, data collected as part of current and ongoing monitoring programs of the mine, the Leviathan-Bryant Creek watershed, and the East Fork of the Carson River, as well as any additional risk assessment data or conclusions, will be examined. The evaluation will consist of analyzing existing data to determine sources of hazardous substances releases, exposure pathways, and exposure to natural resources, and to determine and quantify injury. Additional literature and document reviews will be conducted, as appropriate, to develop injury thresholds against which environmental exposure data can be compared, or to address any identified data gaps. Based on the results of Phase I, the Trustees may conduct additional assessment studies (Phase II). As described in subsequent sections of this chapter, certain data gaps have already been identified by the Trustees, and a set of focused studies has been proposed to address these data gaps. However, additional data gaps may be identified and supplemental studies may be proposed in the future. Before conducting studies, the Trustees will prepare study-specific protocols and operating procedures that will provide details of study implementation.

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1. Baseline conditions are the conditions that would have existed at the assessment area had the release of the hazardous substance not occurred [43 CFR § 11.14(e)].

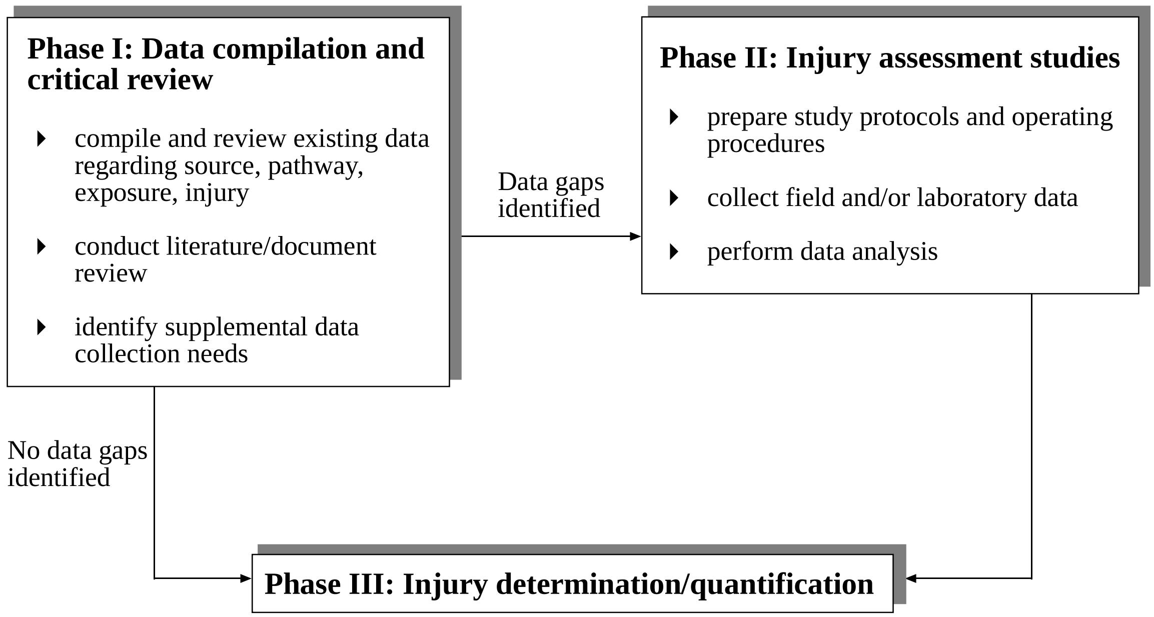


Figure 4.1. Phased injury assessment approach to be implemented by the Trustees.

- **Phase II: Injury assessment studies.** If data gaps are identified following Phase I, site-specific field or laboratory studies may be implemented to complete data gathering for injury determination and quantification.

- **Phase III: Injury determination and quantification.** The results of the Phase I data review and any Phase II data collection will be evaluated for the purposes of a comprehensive injury determination and quantification.

Consistent with the DOI regulations, injury determination and quantification will be evaluated resource by resource, as described in this chapter. However, natural resources and the ecological services they provide are interdependent. For example, surface water, bed, bank, and suspended sediments, floodplain soils, and riparian vegetation together provide habitat — and lateral and longitudinal connectivity between habitats — for aquatic biota, semi-aquatic biota, and upland biota dependent on access to the creeks in the area. Hence, injuries to individual natural resources may cause ecosystem-level service reductions. The Trustees will consider these interdependent ecosystem-level service losses when preparing their injury assessment.

Injury determination and quantification approaches for each natural resource are described in the following sections.

4.3 Surface Water Resources

According to DOI NRDA regulations, surface water resources include surface water and suspended, bed, and bank sediments [43 CFR § 11.14 (pp)]. The injury assessment presented in this section focuses on surface water only. Injury to suspended, bed, and bank sediments is discussed in Section 4.4. Injury to floodplain sediments, included in the category of geological resources, is discussed in Section 4.7.

Initial review of existing data suggests that surface water resources of the assessment area may have been injured as a result of releases of hazardous substances from mining and mineral processing operations at the mine, as well as subsequent operations associated with attempts to contain, treat, or otherwise mitigate such releases. This section presents a summary of proposed approaches to evaluate these surface water injuries.

4.3.1 Data sources

A number of sources of surface water data are available. These sources, listed in order of the actual sampling dates of the data they contain, include:

- Schoen et al., 1995
- Hammermeister and Walmsley, 1985
- Thomas and Lico, 2000
- LRWQCB, 1999
- Smitherman, 1998
- SRK Consulting, 1999
- ENSR, 1999
- Thompson and Welsh, 2000
- USGS, 2001.

The first available surface water quality data were collected by the Anaconda Company between 1954 and 1962. Samples were taken upstream and downstream of the mine and analyzed for pH, sulfate, iron, turbidity, and several metals (Schoen et al., 1995).

Schoen et al. (1995) presents surface water data collected by the Desert Research Institute, University of Nevada, from samples taken from Leviathan and Bryant creeks and analyzed for sulfate, arsenic, and iron, as well as surface water data collected by William F. Jopling (Bureau of Sanitary Engineering, State of California, Department of Public Health) from samples taken from Leviathan Creek upstream and downstream of the mine and analyzed for sulfate, pH, and multiple metals.

From 1981 to 1983, the USGS collected surface water field data, taking measurements of pH, water temperature, conductivity, and major cations and anions near the mine; at four locations downstream of the mine, including Leviathan Creek downstream of Aspen Creek, Leviathan Creek downstream of Mountaineer Creek, and Bryant Creek upstream of Doud Creek; and at potential reference locations in Mountaineer Creek and Aspen Creek (Hammermeister and Walmsley, 1985).

The other sources cited above provide data on concentrations of hazardous substances, including arsenic, cadmium, copper, nickel, zinc, and acidity in surface water, in presumed uncontaminated reference locations (Leviathan Creek and Aspen Creek upstream of the mine, Mountaineer Creek, East Fork of the Carson River upstream of the confluence with Bryant Creek) as well as in the vicinity of the mine and in stream reaches downstream of the mine (Leviathan Creek, Aspen Creek, Bryant Creek, and the East Fork of the Carson River) (see Figure 3.1).

Currently, the USGS is recording water quality data at several locations near the mine and downstream of the mine at 15-60 minute intervals (USGS, 2001). These data are available at http://water.usgs.gov/nwis/current (use sitename = "Leviathan").

4.3.2 Injury definitions

Based on an initial review of these existing data, the relevant NRDA regulatory definitions for the evaluation of injuries to surface water resources in the assessment area include the following:

- Concentrations and duration of hazardous substances in excess of drinking water standards as established by Sections 1411-1416 of the Safe Drinking Water Act (SDWA), or by other federal or state laws or regulations that establish such standards for drinking water, in surface water that was potable before the release [43 CFR § 11.62(b)(1)(i)].

- Concentrations and duration of hazardous substances in excess of water quality criteria established by Section 1401(1)(D) of the SDWA, or by other federal or state laws or regulations that establish such criteria for public water supplies, in surface water that before the discharge or release met the criteria and is a committed use as a public water supply [43 CFR § 11.62(b)(1)(ii)].

- Concentrations and duration of hazardous substances in excess of applicable water quality criteria established by Section 304(a)(1) of the Clean Water Act (CWA), or by other federal or state laws or regulations that establish such criteria, in surface water that before the release met the criteria and is committed use as habitat for aquatic life, water supply, or recreation [43 CFR § 11.62(b)(1)(iii)].

- Concentrations and duration of hazardous substances sufficient to have caused injury to groundwater, air, geologic, or biological resources, when exposed to surface water [43 CFR § 11.62(b)(1)(v)].

Table 4.1 lists specific regulatory standards and criteria that may be used to evaluate injury to surface water in the assessment area. In addition, standards currently under review, such as the EPA's core Federal Water Quality Standards for Indian Country Waters or standards submitted by the Washoe Tribe, may also be used (EPA, 2001a; Washoe Tribe of Nevada and California, 2000).

Table 4.1. Relevant regulatory standards and criteria and relationship to injury definitions.

		Injury definitions	
Relevant standards and criteria		**Concentrations in excess of water quality criteria or standards**	**Concentrations in excess of drinking water standards**
EPA Ambient Water Quality Criteria (human health and welfare protection)			✓
EPA Ambient Water Quality Criteria (freshwater aquatic life protection)		✓	
Safe Drinking Water Act	MCL[a]		✓
	MCLG[b]		✓
	SDWR[c]		✓
California Regional Water Quality Control Board water quality objectives			✓
California water quality numeric criteria (protection of aquatic life)		✓	
California Department of Health Service	MCL[d]	✓	
	Secondary MCL[d]		✓
Nevada water quality criteria (municipal or domestic supply)			✓
Nevada water quality criteria (protection of aquatic life)		✓	

a. MCL = Maximum Contaminant Levels, a federally enforceable maximum permissible level of a water contaminant that is delivered to any user of a public water system.
b. MCLG = Maximum Contaminant Level Goals, nonenforceable health goals.
c. SDWR = Secondary Drinking Water Regulations, nonenforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water.
d. Secondary MCL = Maximum Contaminant Level, nonenforceable health goal.

In addition to the above injury definitions, an injury to surface water resources may result from concentrations and duration of hazardous substances, in excess of baseline conditions, sufficient to cause a loss of services provided by surface water resources to the general public in addition to unique service losses to members of the Washoe Tribe. Such loss of services may result from health risks posed by the use of surface water, in and of itself, or the cumulative health risk in conjunction with uses of other resources in the assessment area which have been exposed to hazardous substances. Loss of services may also result from perception of contamination of surface water resources.

Although this latter definition is not listed in the NRDA regulations [43 CFR § 11.62(b)(1)], the regulations do not forbid the use of other injury definitions [43 CFR § 11.11]. Since loss of services provided by resources may be used to determine the amount of damages, if services are lost because of the release of hazardous substances, even if no other definitions of injury are met, the resources should be considered injured.

Pursuant to Section 304 of the CWA, the EPA establishes national recommended ambient water quality criteria that are generally applicable to the water of the United States. The criteria address risks to both human health and aquatic life. The criteria that are designated to protect aquatic life are generally referred to as aquatic life criteria (ALC). The EPA recommends the use of dissolved metal concentrations for establishing compliance with ALC (58 FR 32131, June 8, 1993).

On May 18, 2000, the EPA promulgated water quality standards for California to fill a gap in California water quality standards that was created in 1994 when a court overturned the State's water quality criteria for priority toxic pollutants. These EPA standards became the legally enforceable water quality standards in California for all purposes and programs under the CWA.

To control the level of contaminants in the nation's drinking water, the EPA established three drinking water standards based on total recoverable metals. The Maximum Contaminant Levels (MCL) are the highest level of a contaminant that is allowed in drinking water. The MCL Goals (MCLG) are a nonenforceable health goal that is set at a level at which no known or anticipated adverse effect on human health occurs and which allows an adequate margin of safety. The Secondary Drinking Water Regulations (SDWR) are also nonenforceable federal guidelines regarding cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) of drinking water. The Trustees propose using MCLs and SDWRs to evaluate injuries to drinking water services.

Nevada also established quality standards to protect aquatic life and other beneficial uses such as recreation and domestic and municipal water supplies (State of Nevada, 1998). Furthermore, the LRWQCB established specific numerical water quality objectives for Bryant Creek Basin for beneficial uses based on the Safe Drinking Water Standards (LRWQCB, 2001b).

4.3.3 Calculation of ALC

The toxicity of cadmium, copper, nickel, and zinc to aquatic species varies with water hardness. Water hardness is a measure of the concentration of calcium and magnesium present in water and is expressed as milligrams of calcium carbonate ($CaCO_3$) per liter. Cadmium, copper, nickel, and zinc are more toxic to aquatic biota at low hardness than at higher hardness values.

The ALC for cadmium, copper, nickel, and zinc are expressed in terms of a criterion maximum concentration (CMC, acute criterion) and a criterion continuous concentration (CCC, chronic criterion). The acute criterion is an estimate of the highest concentration of a substance in surface water to which an aquatic community can be exposed briefly without an unacceptable effect. The chronic criterion is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed indefinitely without an unacceptable effect (63 FR 68364, December 10, 1998).

The acute and chronic criteria are each one of three components that constitute an ALC (EPA, 1987). The other two parts are the averaging period and the frequency of allowable exceedence. For cadmium, copper, nickel, and zinc, the acute averaging period is 1 hour, the chronic averaging period is 4 days, and the frequency of allowable exceedence for both chronic and acute criteria is no more than once every 3 years. For example, the chronic ALC for copper at a hardness value of 100 mg/L is a 4-day average concentration of 9 μg/L not to be exceeded more than once every 3 years.

The equations developed by the EPA to calculate freshwater total recoverable metals criteria (μg/L) are:

$$\text{acute criteria} = \exp\,[m_A\ (\ln(\text{hardness}))+b_A]$$

$$\text{chronic criteria} = \exp\,[m_c\ (\ln(\text{hardness}))+b_c].$$

Values for the constants m and b for these equations for cadmium, copper, nickel, and zinc are presented in Tables 4.2 through 4.4 depending on the criteria considered. Table 4.2 shows the values for the constants m and b used by the EPA, Table 4.3 the values used by the State of California, and Table 4.4 the values used by the State of Nevada.

Table 4.2. Constants m and b for acute and chronic ALC used in EPA water quality criteria.

	Acute criteria		Chronic criteria	
Metal	m_A	b_A	m_C	b_C
Cadmium[a]	1.0166	-3.924	0.7409	-4.719
Copper[b]	0.9422	-1.700	0.8545	-1.702
Nickel[b]	0.8460	2.255	0.8460	0.0584
Zinc[b]	0.8473	0.884	0.8473	0.884

a. EPA, 2001b.
b. EPA, 1999b.

Table 4.3. Constants m and b for acute and chronic ALC used in California's water quality criteria.

	Acute criteria		Chronic criteria	
Metal	m_A	b_A	m_C	b_C
Cadmium	1.128	-3.6867	0.7852	-2.715
Copper	0.9422	-1.700	0.8545	-1.702
Nickel	0.8460	2.255	0.8460	0.0584
Zinc	0.8473	0.884	0.8473	0.884

Source: 40 CFR § 131.38.

Table 4.4. Constants m and b for acute and chronic ALC used in the Nevada Administrative Code (NAC).

	Acute criteria		Chronic criteria	
Metal	m_A	b_A	m_C	b_C
Cadmium	1.128	-3.828	0.7852	-3.490
Copper	0.9422	-1.464	0.8545	-1.465
Nickel	0.8460	3.3612	0.8460	1.1645
Zinc	0.8473	0.8604	0.8473	0.7614

Source: State of Nevada, 1998.

The dissolved metals criteria are derived by multiplying the total recoverable metal acute and chronic criteria by a conversion factor. The EPA's and the State of California's conversion factors for cadmium are themselves hardness dependent (Table 4.5). Table 4.6 shows the conversion factors used by the State of Nevada.

Table 4.5. EPA's and State of California's parameters used to convert the total acute (CMC) and chronic (CCC) criteria to dissolved criteria.

Metal	CMC conversion factor	CCC conversion factor
Cadmium[a]	1.136672-[(ln hardness) (0.041838)]	1.101672-[(ln hardness) (0.041838)]
Copper[b]	0.960	0.960
Nickel[b]	0.998	0.997
Zinc[b]	0.978	0.986

a. EPA, 2001b.
b. EPA, 1999b.

Table 4.6. Nevada Administrative Code (NAC)'s parameters used to convert the total acute (CMC) and chronic (CCC) criteria to dissolved criteria.

Metal	CMC conversion factor	CCC conversion factor
Cadmium	0.85	0.85
Copper	0.85	0.85
Nickel	0.85	0.85
Zinc	0.85	0.85

Source: State of Nevada, 1998.

The equations are applicable for hardness values within the range of 0 to 400 mg/L $CaCO_3$ [40 CFR § 131.36 (c)(4)(i)].

In evaluating exceedences of ALCs, the Trustees propose applying the measured sample-specific hardness rather than using an assumed, or default, hardness. However, if hardness is greater than 400 mg/L, a value of 400 mg/L will be applied to calculate the ALC.

Table 4.7 presents examples of applicable surface water criteria and standards calculated over a range of water hardness values. The Trustees will use the most stringent applicable standard to evaluate injury to surface water, including submitted standards if approved.

In addition to the numerical limits presented in Table 4.7, the State of California has established water quality objectives that include narrative limits for constituents or characteristics of water designed to protect specific uses of surface water under the California Porter-Cologne Water Quality Control Act (LRWQCB, 2001b). Narrative limits have been developed for color, taste, and odor. These narrative limits provide that color, taste, and odor shall not “cause nuisance or adversely affect the water for beneficial uses.” The Trustees may consider these narrative limits in evaluating surface water injury.

4.3.4 Injury determination approaches

Each of the injury definitions identified in Section 4.3.2 consists of several components. Table 4.8 summarizes the components of each definition and the approaches that may be taken in assessing each component.

An initial review of available data suggests that surface water resources have been injured according to the injury definitions presented in Table 4.8. For example, Figure 4.2 presents the magnitude of exceedences of the SDWA MCL (5 μg/L) for dissolved arsenic in surface water. Samples collected in surface waters near the mine, in Leviathan, Aspen, and Bryant creeks, exceeded the MCL for arsenic (see map with reference and assessment area site locations in Figure 3.1). Moreover, for purposes of evaluating exceedences of the MCL, the Trustees may use total metal concentrations in surface water, and as shown in Figure 3.8, total arsenic is likely to exceed dissolved arsenic. Therefore, the frequency and magnitude of arsenic exceedences may be greater than those shown in Figure 4.2. Nonetheless, most of the data readily available at this time were presented as dissolved metal concentrations, and therefore dissolved metal concentrations are used here as illustrations of the injury approach.

Figure 4.3 shows that dissolved copper concentrations in surface water near the mine and in Leviathan and Bryant creeks exceed the acute ALC for the protection of aquatic life.

Surface water criteria standards for pH are also violated at several locations, including near the mine and in Leviathan Creek, Aspen Creek, and Bryant Creek (Figure 4.4).

Table 4.7. Examples of applicable surface water criteria and standards for the assessment area at different hardness values (criteria/standard concentrations in μg/L).

Injury definitions	pH	Arsenic	Cadmium			Copper			Nickel			Zinc		
Hardness (mg/L)			25	250	400	25	250	400	25	250	400	25	250	400
EPA national recommended ambient water quality criteria (protection of aquatic life) — acute criteria[a] (ALC)		340	0.5	4.9	7.7	3.6	31.9	49.6	145.0	1,016.5	1,512.9	36.2	254.7	379.3
EPA national recommended ambient water quality criteria (protection of aquatic life) — chronic criteria[a] (ALC)	6.5-9[b]	150	0.1	0.5	0.6	2.7	19.6	29.3	16.1	112.9	168.0	36.5	256.8	382.4
EPA ambient water quality criteria (protection of human health and welfare) — non-cancer health effects in drinking water[a]							1300			610			9,100	
EPA ambient water quality criteria (protection of human health and welfare) — one-in-a-million cancer risk estimate in drinking[a] water		0.018												
Safe Drinking Water Act[c] MCL		50[d]		5			TT[e]							
MCLG		0		5			1,300							
SDWR	6.5-8.5						1,000						5,000	
California Regional Water Quality Control Board water quality objectives[f]	6.5-8.8	50					20							
California water quality numeric criteria (protection of aquatic life) — acute criteria[g] (ALC)		340	0.95	12	19	3.6	31.9	49.6	145.0	1,016.5	1,512.9	36.2	254.7	379.3
California water quality numeric criteria (protection of aquatic life) — chronic criteria[g] (ALC)		150	0.8	4.4	6.2	2.7	19.6	29.3	16.1	112.9	168.0	36.5	256.8	382.4
California Department of Health Service[h] MCL		50		5			1,300			100				
Secondary MCL							1,000						5,000	

Table 4.7. Examples of applicable surface water criteria and standards for the assessment area at different hardness values (criteria/standard concentration in µg/L) (cont.)

Injury definitions	pH	Arsenic	Cadmium			Copper			Nickel			Zinc		
Nevada water quality criteria (municipal or domestic supply)[i]	6.5-9.0[j]	50		5						13.4				
Nevada water quality criteria (protection of aquatic life) — acute criteria[i] (ALC)	6.5-9.0	342	0.7	9.4	15.9	4.1	35.7	55.6	373.1	2,617.1	3,895.0	30.8	216.2	322.0
Nevada water quality criteria (protection of aquatic life) — chronic criteria[i] (ALC)	6.5-9.0	180	0.3	2.0	2.8	3.1	22.0	32.8	41.5	290.9	433.0	27.8	195.8	291.6

Notes: MCL = Maximum Contaminant Level, a federally enforceable maximum permissible level of a water contaminant that is delivered to any user of a public water system.
MCLG = Maximum Contaminant Level Goals, nonenforceable health goals.
SDWR = Secondary Drinking Water Regulations, federal guidelines regarding taste, odor, color, and certain nonaesthetic effects of drinking water.
Secondary MCL = Secondary Maximum Contaminant Level, nonenforceable.

a. Clean Water Act — Section 304(a).
b. EPA, 1976.
c. EPA, 2000c.
d. 40 CFR §141. This standard will remain in effect until January 2006, when a new standard of 10 µg/L will take effect (EPA, 2002).
e. "Treatment Technique:" Copper action level 1,300 µg/L.
f. LRWQCB, 2001b.
g. 40 CFR § 131.
h. California Code of Regulations (CCR) — Title 22.
i. State of Nevada, 1998.
j. Applies to Bryant Creek (NAC 445A.148) and East Fork Carson River (NAC 445A.149) within this assessment area (State of Nevada, 1998); for other reaches of creeks in assessment area, pH = 5 – 9 applies.

Table 4.8. Components of relevant surface water injury definitions.

Injury definition	Definition components	Evaluation approach
Water quality exceedences [43 CFR § 11.62(b)(1)(iii)]	Surface waters are a committed use as aquatic life habitat, water supply, or recreation.	Determine whether assessment area water bodies have or had committed uses.
	Concentrations and duration of hazardous substances are in excess of applicable water quality criteria.	Perform temporal and spatial comparisons of surface water concentrations to state, tribal and federal water quality criteria/standards.
	Criteria were not exceeded before release.	Compare baseline conditions to state, tribal, and federal water quality criteria.
Drinking water standards exceedences [43 CFR § 11.62 (b)(1)(i)]	Concentrations and duration of hazardous substances are in excess of applicable drinking water standards.	Perform temporal and spatial comparisons of surface water concentrations to state, tribal, and federal standards.
	Water was potable before release.	Compare baseline conditions to drinking water standards.
Biological resources injured when exposed to surface water/sediments [43 CFR § 11.62(b)(1)(v)]	Biological resources are injured when exposed to surface water/sediments.	Determine whether natural resources have been injured as a result of exposure to surface water/sediments.
Baseline exceedence	Surface water resources are injured when concentrations of hazardous substances exceed baseline.	Determine whether concentrations exceed baseline.
	Baseline exceedences cause loss of services to the Washoe Tribe.	Determine whether surface water services have been lost as a result of exceedences.

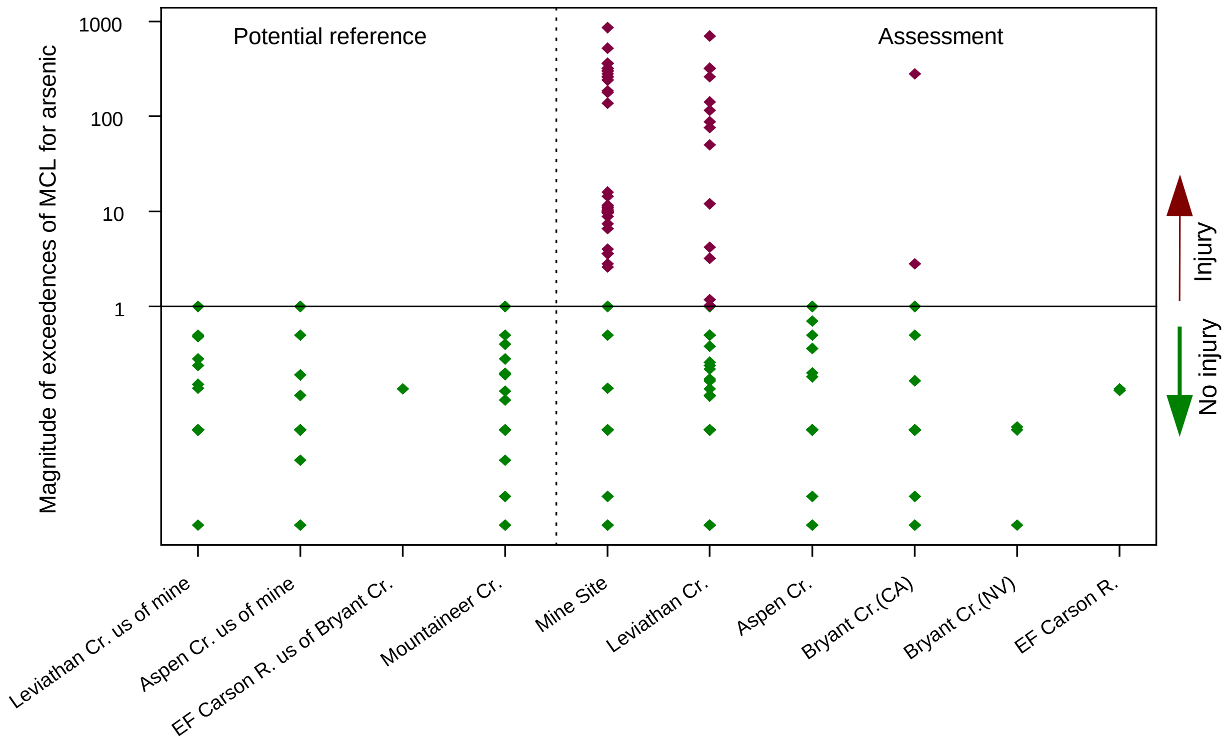


Figure 4.2. Magnitude of exceedences of MCL for dissolved arsenic in surface water at 10 sites in the Leviathan-Bryant Creek watershed and the East Fork Carson River. Magnitude of exceedence calculated as concentration of arsenic in surface water divided by MCL. Exceedence factors >1 represent samples where concentrations exceed injury thresholds.

Sources: LRWQCB, 1999; Thomas and Lico, 2000; Thompson and Welsh, 2000.

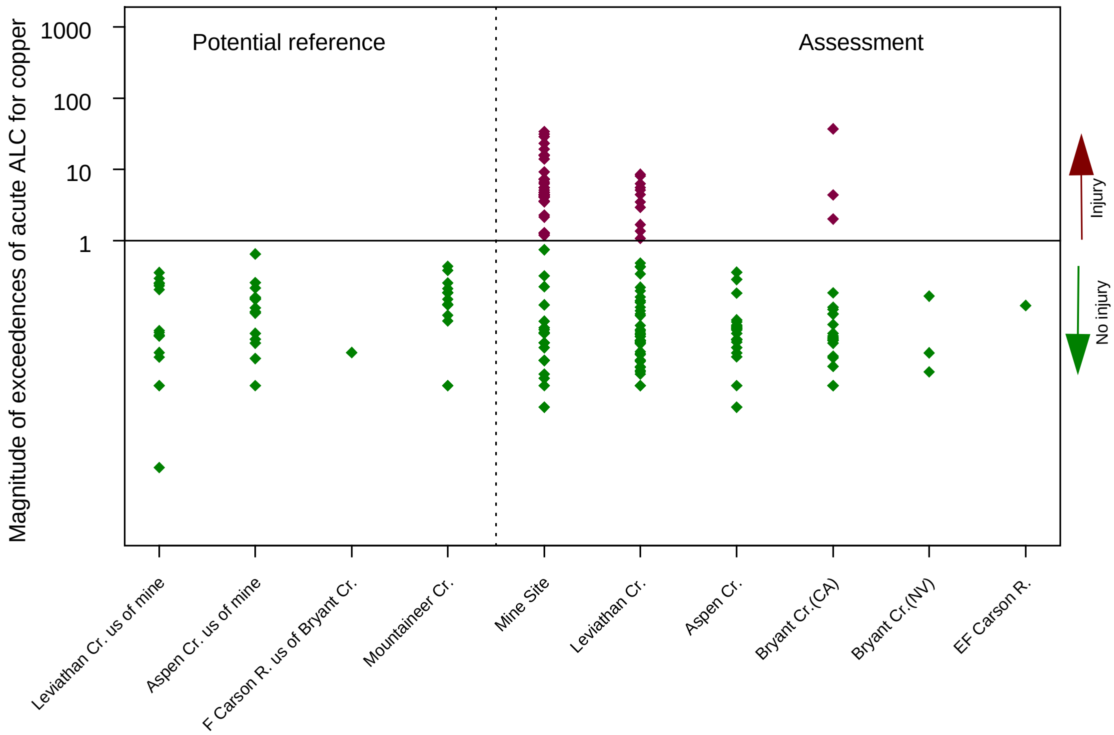


Figure 4.3. Magnitude of exceedences of acute ALC for dissolved copper concentrations at 10 sites in the Leviathan-Bryant Creek watershed and the East Fork Carson River. Magnitude of exceedence calculated as concentration of copper in surface water divided by ALC. Sample-specific criterion values are calculated using measured hardness. Exceedence factors >1 represent samples where concentrations exceed injury thresholds (records where the detection limit was higher than the acute ALC were eliminated from the graph to avoid false exceedences).

Sources: LRWQCB, 1999; Thomas and Lico, 2000; Thompson and Welsh, 2000.

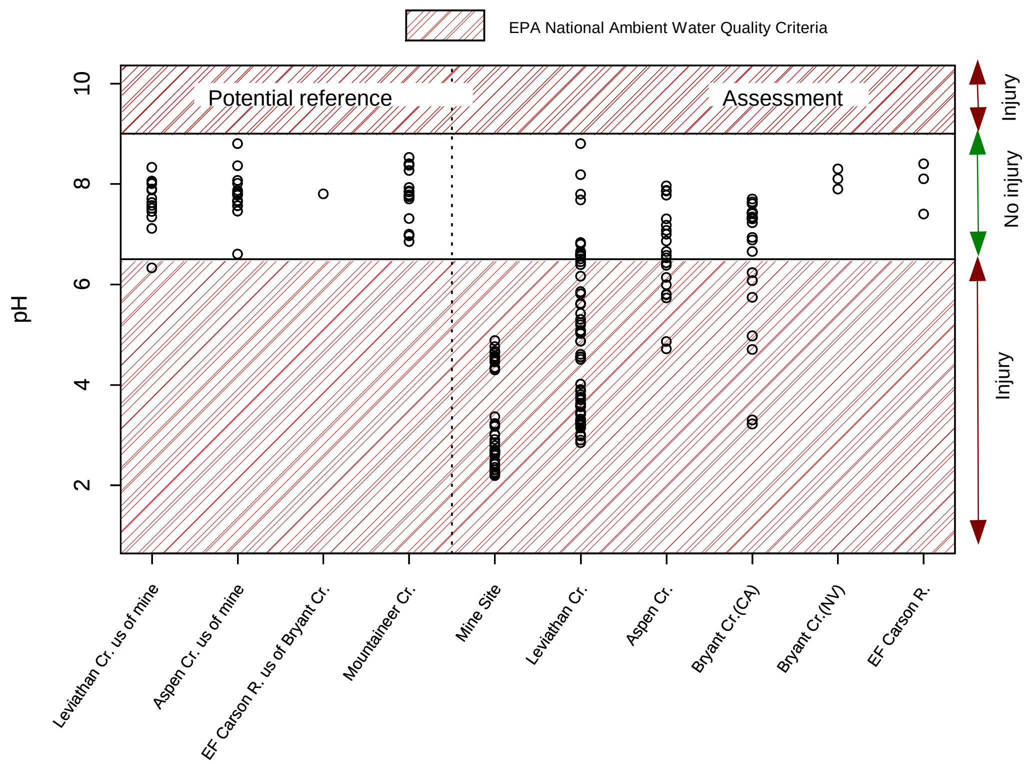


Figure 4.4. Surface water pH measured at 10 sites in the Leviathan-Bryant Creek watershed and the East Fork Carson River relative to water quality standards.

Sources: LRWQCB, 1999; Thomas and Lico, 2000; Thompson and Welsh, 2000.

A comprehensive evaluation of surface water data will be conducted to evaluate injuries using this approach.

In addition to conducting temporal and spatial comparisons of surface water concentrations to state, tribal, and federal water quality criteria/standards, the Trustees will also evaluate baseline conditions (see Table 4.8). Baseline refers to the conditions that would have existed had the releases of hazardous substances not occurred [43 § 11.72 (a)].

The DOI regulations suggest using historical data to evaluate baseline conditions [43 CFR § 11.72 (c)]. However, no quantitative historical data exist to describe baseline surface water conditions in the assessment area, other than anecdotal observations of “a clear and clean creek” with “many fish” (Various authors, 1969). Therefore, field data collected at reference areas will be used to define baseline. Reference areas will be selected by the Trustees to reflect, to the extent feasible, the influence of natural weathering of mineralized deposits and processes that result from historical and ongoing nonmining-related human activities and land uses in the assessment area, including the influence of water withdrawals on surface water baseline.

4.3.5 Pathway evaluation

A preliminary evaluation of pathways from discharge sources to surface water resources in the assessment area suggests that pathways include direct discharges of hazardous substances to surface water, soil runoff, groundwater transport, and surface water/sediment transport (Figure 4.5).

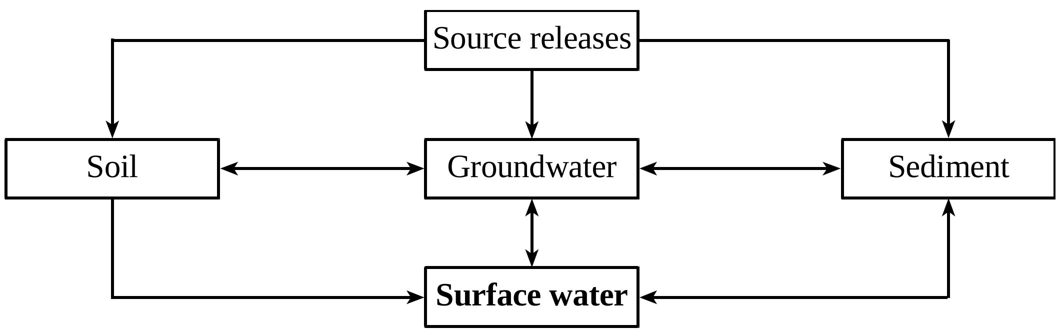


Figure 4.5. Potential surface water exposure pathways.

For example, evaporation ponds receiving acid mine drainage from various springs and seeps have overflowed during the winter and early spring months, causing a release of acid mine drainage into Leviathan Creek (Montgomery Watson, 2001). Leaching of metals from mine waste piles results in releases of dissolved metals to surface water. Resuspension of contaminated sediments can also expose surface water resources to metals. High metal concentrations in the sediments of Leviathan Creek serve as a potential transport pathway to the surface waters of Leviathan and Bryant creeks.

The Trustees propose using existing data to demonstrate “the presence of the . . . hazardous substances in sufficient concentrations in the pathway resource” [43 § 11.63(a)(2)].

4.3.6 Injury quantification approaches

Quantification of injuries to surface water resources will include evaluation of:

- the spatial extent of injuries throughout the assessment area
- the temporal extent of injuries throughout the assessment area.

Geographic information system (GIS) platforms may be used to facilitate spatial quantification using the database prepared in the Phase I assessment. A preliminary evaluation of available surface water data suggests that surface water arsenic and copper concentrations have exceeded surface water injury thresholds at least as far downstream of the mine as Bryant Creek downstream of Mountaineer Creek (Figures 4.2 to 4.4). Concentrations are greatest proximate to the mine.

The temporal extent of injuries will be quantified through examination of available historical surface water metal concentration data and other site records.

4.3.7 Surface water as a pathway of injury to other resources

In addition to direct injuries to surface water associated with the exceedences of ALC, surface waters in the assessment area may also be injured because other natural resources may have been injured as a result of exposure to contaminated surface water [43 CFR § 11.62(b)(1)(v)]. For example, as described in Section 4.6, fish and benthic invertebrates may be injured by exposure to contaminated surface waters.

4.3.8 Additional studies

Initial review of available data suggests that surface waters may be injured based on injury definitions presented in Table 4.8. In addition to the Phase I data evaluation (see Figure 3.1), two additional surface water injury studies are proposed: (1) water quality mass balance modeling, and (2) monitoring of ephemeral “pulse” events.

Study justification

A review of existing data suggests that concentrations of hazardous substances in the creeks downstream of the mine have demonstrated extreme seasonal fluctuations in response to precipitation. Infiltration of precipitation into and through the open pit and overburden piles creates acid mine drainage that discharges directly into Leviathan Creek (Trustees for the Leviathan Mine Site, 1998). Evaporation ponds designed to collect and evaporate acid mine drainage up until early spring have also contributed to acid mine drainage in the past when the storage capacity of the ponds was exceeded because of increased surface runoff with precipitation (LRWQCB, 2001a). During these ephemeral "pulse" events, copper concentrations in Bryant Creek increase by an order of magnitude and pH drops by roughly three pH units, which equates to roughly a thousandfold increase in acidity (LRWQCB, 1999; Figure 4.6). Furthermore, acute exposure of fish to acid mine drainage has resulted in fish kills as far downstream as Dresslerville during pulses (Trelease, 1959), suggesting that, at least historically, pulses may have exposed both lower Bryant Creek and the East Fork Carson River to releases of hazardous substances from the mine. However, the downstream extent of the metal contamination during these events has not been monitored. The purpose of the proposed additional studies is to (1) develop a retrospective model to evaluate the potential downstream extent of historical pulses, thereby facilitating injury quantification; and (2) to implement a monitoring program to assess whether pulses are still ongoing and to characterize water quality conditions during any such pulses.

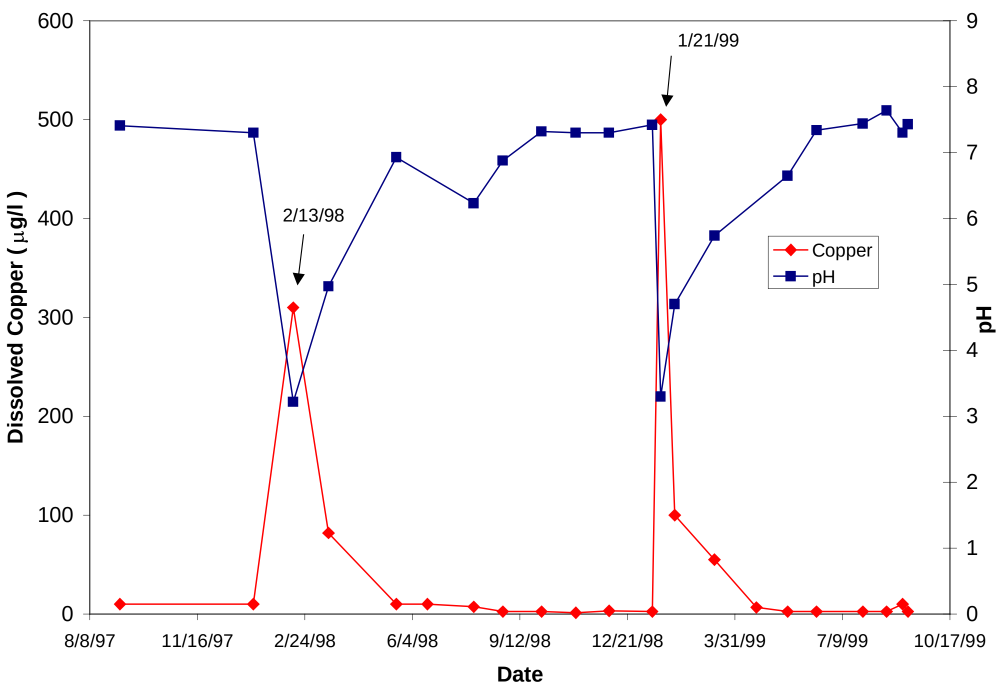


Figure 4.6. Dissolved copper concentrations (µg/L) and pH in surface water of Bryant Creek downstream of confluence of Mountaineer and Leviathan creeks.

Source: LRWQCB, 1999.

Water quality modeling

Objectives. Knowledge of water quality downstream of the mine will assist in efforts to estimate the spatial and temporal extent of injuries to surface water, sediment, and aquatic biota. The principal objective of the water quality model is to inform this quantification through an evaluation of the downstream extent of hazardous conditions during pulse events. The model will use previously collected information to estimate water quality conditions during past releases of hazardous substances. In addition, the model may also be used predictively in evaluating long-term impacts of future releases of hazardous substances from the mine.

Approach. A simple downstream dilution and transport model will be used to estimate water quality conditions downstream of the mine. The basic principle of the model is the conservation of mass, where differences between inputs and outputs of the model in any particular interval of time, within any particular volume in space, are equal to the net sum of the production, retention, and decay processes within the volume (Beltran, 2001). Four processes will be considered: transport processes such as advection (flow) and diffusion; geochemical processes associated with chemical transformation, equilibrium partitioning, and adsorption-desorption; precipitation reactions; and in-stream dilution.

Figure 4.7 depicts the anticipated structure of the model. The model will contain a series of segments, each representing a defined stream reach. Inputs reflect water quality conditions entering the stream reach. The “box model” represents processes affecting concentrations and the distribution of dissolved, sorbed, and precipitated chemical forms. A benthic segment compartment will be included in the box model to account for sediment-surface water interactions. The output box represents water quality conditions at the downstream end of the longitudinal section of the river considered.

The Trustees propose to evaluate water quality concentrations during pulses in six reaches of the Leviathan-Bryant Creek watershed and East Fork Carson River from 1980 to the present (Figure 4.8). These reaches have been selected to capture principal changes in hydrology. Leviathan Creek 1 (LC-1), from downstream of Aspen Creek to upstream of the confluence of Mountaineer and Leviathan creeks, is the most upstream segment. Input data for LC-1 will be water quality data monitored downstream of the confluence of Aspen Creek with Leviathan Creek. Bryant Creek segment 1 (BC-1), from LC-1 to upstream of the confluence of Barney Riley Creek with Bryant Creek, will be used to characterize water quality conditions after dilution by Mountaineer Creek. Bryant Creek segment 2 (BC-2), from BC-1 to upstream of the confluence of Doud Springs with Bryant Creek, will be used to characterize water quality conditions after dilution by Barney Riley Creek. Bryant Creek segment 3 (BC-3), from BC-3 to upstream of the confluence of the East Fork Carson River by Bryant Creek, will be used to characterize water quality conditions after dilution by Doud Springs and reduction of flow by the upper and lower River Ranch irrigation diversions. East Fork Carson River segment 1 (EC-1), from BC-3 to upstream

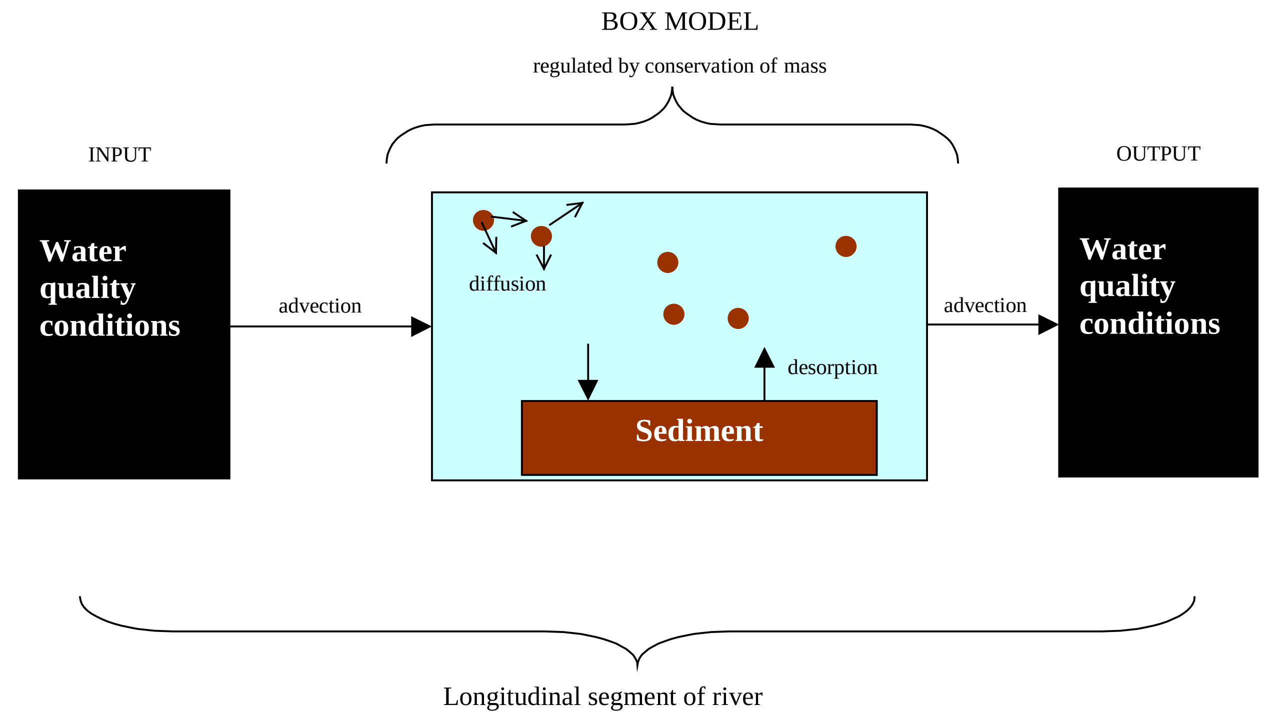


Figure 4.7. Anticipated structure of water quality model to be used to evaluate hazardous conditions at locations downstream of the mine.

of the confluence of East Fork Carson River by Indian Creek, will be used to characterize water quality conditions after dilution by Indian Creek. Finally, East Fork Carson River segment 2 (EC-2), from EC-1 a few miles downstream, will be used to characterize water quality conditions in East Fork Carson River downstream of Indian Creek.

It is anticipated that the META4 Simulation Program (Medine and Martin, 1998), or a similar model framework, will be used to simulate dilution, transport, and geochemical processes in the segments. The META4 model was tested as part of studies for the Clear Creek Superfund Site in the Clear Creek watershed (Colorado) to describe the transport and transformation of copper, cadmium, and zinc (Medine, 1997a, 1997b). It has also been used in the Alamosa River (Medine, 1997c) and the Arkansas River (Medine and Martin, 1994) in Colorado to evaluate the impact of leachate from mining tailings on metal concentrations in these waterbodies. The model uses the basic transport scheme of the Water Analysis Simulation Program (WASP) developed by the EPA (Ambrose et al., 1993). Algorithms for the simulation of metals aqueous speciation, sorption, chemical precipitation, and kinetics were added to this basic structure, resulting in

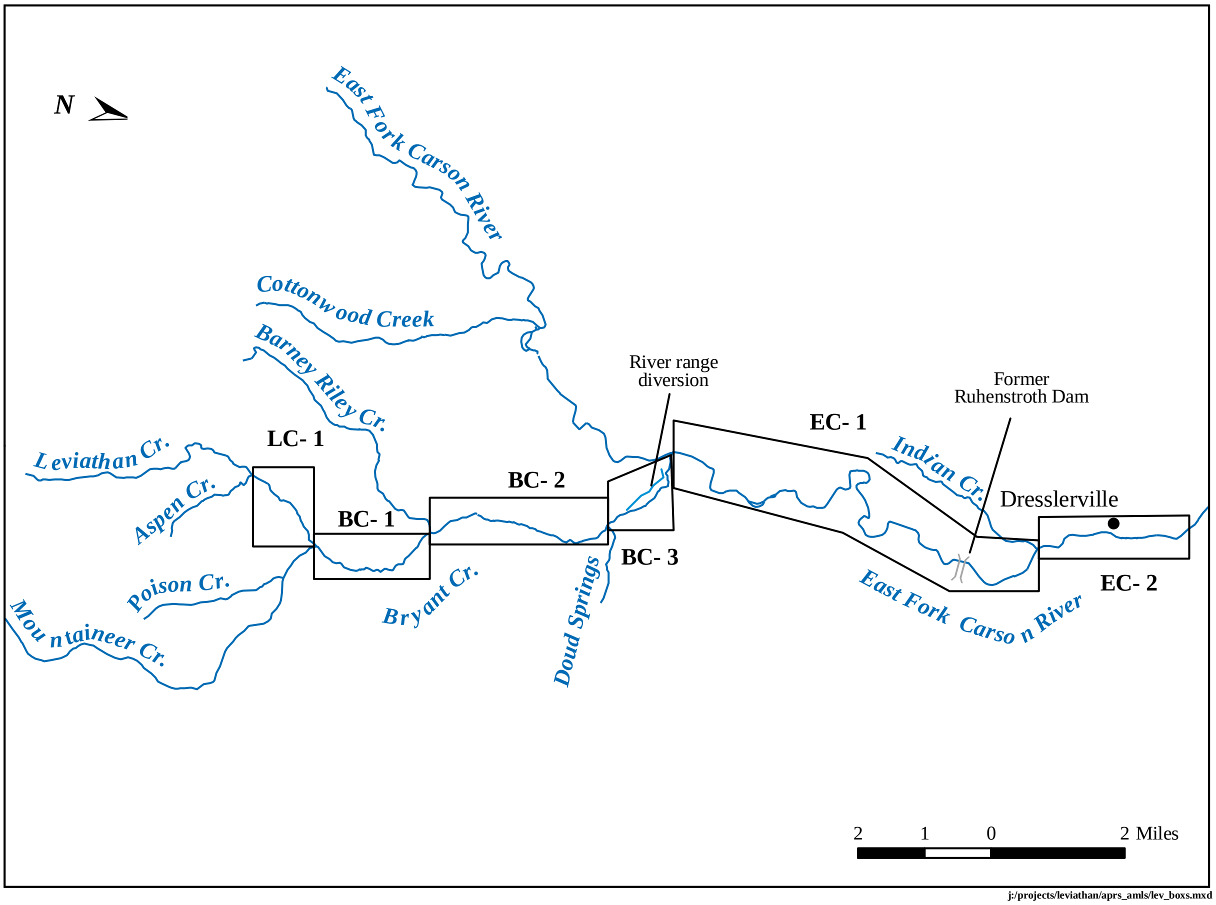


Figure 4.8. Model segmentation of the Leviathan-Bryant Creek watershed and East Fork Carson River. The boxes represent the location of the box models described in the text.

META4. The state variables in META4 are trace metals, anions and cations, pH, and three arbitrary solids. For each of the state variables, and for each control volume and model time step, META4 will numerically solve a mass balance equation. The chemical species considered by META4 include dissolved, sorbed, and precipitated forms. Dissolved forms include both free ions and complexes. Sorbed forms are those associated with solids. Precipitated forms are those that form a solid phase.

A temporal component will be included in the water quality model to take into account effects of water withdrawal in Bryant Creek and East Fork Carson River on the extent of hazardous conditions downstream of the mine.

The Trustees anticipate development and validation of the model using existing data. Model parameters will be calibrated to obtain the desired level of accuracy of model outputs. Uncertainty in the model parameters and model outputs will be evaluated. Additionally, a sensitivity analysis of the model parameters will be performed.

Water quality study plan

Objective. Ephemeral “pulses” of acid and metals have been released from the mine in the past. However, the frequency, duration, magnitude, and spatial extent of these pulses are not currently being characterized. The primary objective of the proposed water quality sampling is to design a sampling protocol to determine whether pulses are ongoing at the site, and if so, to characterize the nature and downstream extent of water quality during these events. The sampling will be conducted to provide data that also could be used in the proposed water quality model (see above).

Approach. Design and execution of the water quality study will be preceded by Phase I data compilation and review. In addition, preliminary water quality modeling may be performed to assist in development of the study. It is anticipated that the proposed study could include two components:

1. *Continuous monitoring* of water pH, conductivity, and temperature in Leviathan Creek downstream of the site to detect pulse releases from the site. *In situ* water quality monitors will be used to collect continuous water quality data. A monitor placed in Leviathan Creek just downstream of its confluence with Aspen Creek will be used to detect pulses of releases from the mine site. Drops in pH will be used to identify pulse releases from the site, and pH values below a specific level for a minimum duration (to be determined based on a review of existing water quality data) will be used to trigger the collection of water samples for metal analysis (as described in the second component, below). The output of the water quality monitor in Leviathan Creek downstream of Aspen Creek may also be transferred via satellite link for real-time remote monitoring of conditions by study personnel.

    Continuous water quality monitors may also be placed in other locations downstream of the mine site that correspond to the water quality model segments (Figure 4.8). The need for and placement of additional continuous water quality monitors will be determined as part of the development of a detailed study protocol.

    Based on information gathered in this first study component, a second study component may be implemented:

2. *Collection of water samples during pulses* from areas downstream of the site, such as Leviathan Creek, Bryant Creek, and East Fork Carson River, for analysis of metal concentrations and other water quality parameters during pulse releases. These samples would provide information on the downstream extent of elevated metal concentrations and altered water quality during pulse releases. The samples could be collected by automatic samplers programmed to begin sampling based on the magnitude and duration of low pH excursions monitored by the continuous water quality monitor in Leviathan Creek downstream of Aspen Creek. The water quality monitors and automatic samplers could be linked via satellite, radio signal, and/or cable connection.

   During a pulse event, the automatic samplers would collect water samples on a regular basis (e.g., hourly). Study personnel would visit each sampler soon after sampling begins to collect, filter, and preserve samples and to replace sampling bottles. Water samples would be sent to an analytical laboratory for analysis of total and dissolved metals, cations, anions, and other parameters.

   Automatic samplers may be placed at up to six locations downstream of the mine site (Figure 4.9). The need for and exact locations of the samplers will be determined as part of the development of detailed study protocols. As part of study protocol development, a time-of-travel study might also be conducted in Leviathan Creek, Bryant Creek, and East Fork Carson River so that the time of travel for a pulse from the mine to downstream sampling locations could be estimated.

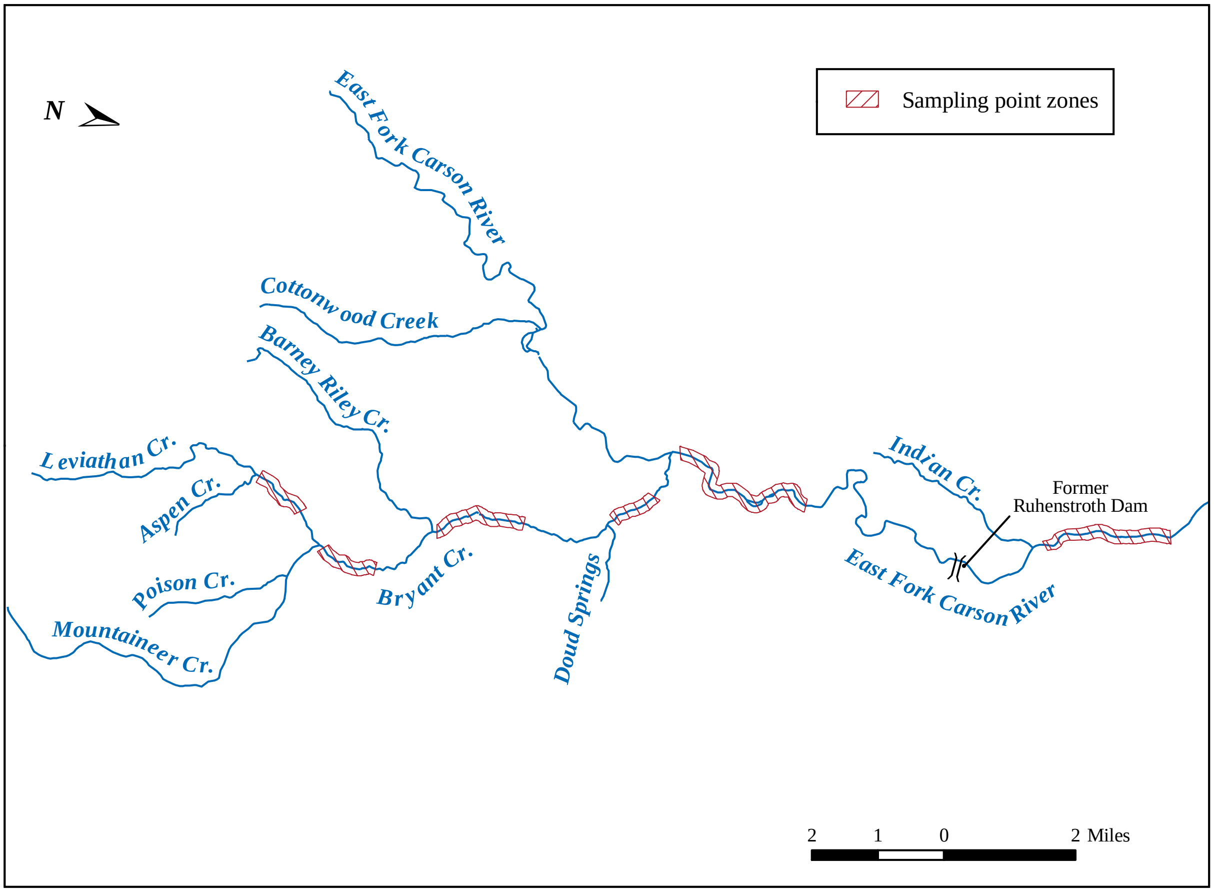
   The results of the time-of-travel study would be used to determine the exact parameters of the automatic sampler programs, including time of sampling initiation (relative to pulse detection), frequency of sample collection, and duration of sample collection.

   Using continuous water quality monitors linked to automatic water samplers would help ensure that pulse releases from the site would be observed and sampled without the need for personnel to be on site continuously. The proper operation of the equipment would be checked through a series of “dry run” tests, and the continued performance of the equipment would be checked weekly during visits by study personnel.

4.4 Sediments

Sediment resources are defined by DOI NRDA regulations both as geologic resources [43 CFR § 11.14 (s)] and as a component of surface water resources as described in Section 4.3 [43 CRF § 11.14 (pp)].

Sediment resources considered in this section include suspended, bed, and bank sediments of waters of the Leviathan-Bryant Creek watershed and East Fork of the Carson River (Figure 3.1).



j:/projects/leviathan/aprs_amls/sampzones.mxd

Figure 4.9. Proposed location zones for automatic water quality samplers.

Initial review of existing data suggests that sediment resources of the assessment area may have been injured as a result of releases of hazardous substances from mining and mineral processing operations at the mine, as well as subsequent operations associated with attempts to contain, treat, or otherwise mitigate such releases. This section presents a summary of proposed approaches to evaluate the injury to bank and floodplain sediments.

4.4.1 Data sources

A number of sources of bed sediment data have been identified. These sources include:

- Herbst, 1995
- Herbst, 1997

- Lawrence, 1998
- ENSR, 1999
- Thomas and Lico, 2000.

During biological sampling, Herbst (1995, 1997) also collected sediment samples in 1995 and 1997 from several locations upstream and downstream of the mine, and in 1992, the USGS collected crayfish bed sediment samples for metal concentration testing at several locations in the Carson River downstream of Markleeville (Lawrence, 1998).

In 1998, the USGS conducted a chemical assessment of streams in the mine and adjacent areas. Samples of fine-grained bed sediment were collected in representative depositional areas for chemical analyses of major and trace elements, total carbon, inorganic carbon, and organic carbon (Thomas and Lico, 2000). That same year, ENSR collected sediment samples from several locations upstream and downstream of the mine to quantify metal concentrations and evaluate the toxicity of these metals to benthic macroinvertebrates (ENSR, 1999).

Two sources of suspended sediment data have been identified:

- Thomas and Lico, 2000
- Thompson and Welsh, 2000.

These sources provide data on concentrations of hazardous substances, including arsenic, cadmium, copper, nickel, and zinc, in suspended sediments of presumed uncontaminated reference locations (Leviathan Creek and Aspen Creek upstream of the mine, Mountaineer Creek, East Fork Carson River upstream of the confluence with Bryant Creek) as well as near the mine and in stream reaches downstream of the mine (Leviathan Creek, Aspen Creek, Bryant Creek, and the East Fork of the Carson River) (see Figure 3.1).

4.4.2 Injury definitions

Based on initial review of existing data, the relevant NRDA regulatory definitions for the evaluation of injuries to sediment resources include the following:

- Concentrations and duration of hazardous substances sufficient to cause injury to biological resources, ground water, or surface water resources that are exposed to sediments [43 CFR § 11.62(b)(v); 11.62(e)(11)].

In addition to the above injury definition, an injury to sediment resources may result from concentrations and duration of hazardous substances, in excess of baseline conditions, sufficient to cause a loss of services provided by sediment resources to the general public in addition to unique service losses to members of the Washoe Tribe. Such loss of services may result from health risks posed by sediment in conjunction with uses of other resources in the assessment area which have been exposed to hazardous substances. Loss of services may also result from perception of contamination of sediment resources.

Although this latter definition is not listed in the NRDA Regulations [43 CFR § 11.62(b)(v); 11.62(e)(11)], they do not forbid the use of other injury definitions [43 CFR § 11.11]. Since loss of services provided by resources may be used to determine the amount of damages, if services are lost because of the release of hazardous substances, even if no other definitions of injury are met, the resources should be considered injured.

Metals accumulated in sediment can be toxic to aquatic biota through direct contact with bed and bank sediments or through movement of the metals from the sediment into the sediment pore water or water column (Burton, 1992). However, no national sediment quality criteria have been developed to protect aquatic biota or wildlife from toxic sediments. Various federal, state, and provincial agencies in North America have developed numerical sediment quality guidelines, and several groups have conducted sediment toxicity texts to assess the quality of freshwater and marine sediments. The sediment quality guidelines currently being used in North America have been developed using a variety of approaches. The approaches that have been selected by individual jurisdictions depend on the receptors considered, the degree of protection afforded, the geographic area to which the values are intended to apply, and the intended uses of the values. MacDonald et al. (2000) assembled published sediment quality guidelines for 28 chemical substances and classified them into two categories according to their original narrative intent: a threshold effect concentration (TEC) and a probable effect concentration (PEC; MacDonald et al., 2000). TECs are intended to identify contaminant concentrations below which harmful effects on sediment-dwelling organisms are not expected to occur. TECs include threshold effect levels, effect range low values, lowest effect levels, minimal effect thresholds, and sediment quality advisory levels (Table 4.9). The PECs are intended to identify contaminant concentrations above which harmful effects on sediment-dwelling organisms are expected to occur frequently. PECs include probable effect levels, effect range median values, severe effect levels, and toxic effect thresholds (Table 4.10). These published sediment quality guidelines were then used to develop two consensus-based sediment quality guidelines for each contaminant, a TEC (last row in Table 4.9) and a PEC (last row in Table 4.10). MacDonald et al. (2000) reported that the consensus PEC numbers for arsenic, cadmium, copper, nickel, and zinc correctly predicted sediment toxicity in 76.9%, 93.7%, 91.8%, 90.6%, and 90%, respectively, of 347 samples from freshwater systems in the United States.

Comparison of sediment quality data to the consensus TECs and PECs will provide an initial means of evaluating loss of services to sediment resources. In addition, evaluation of benthic community composition data will be used to further assess sediment injuries.

Table 4.9. Sediment threshold effect concentrations (TECs) for freshwater sediment.

			Concentration (mg/kg dry wt)					
Name	**Definition**	**Basis**	**As**	**Cd**	**Cu**	**Ni**	**Zn**	**Reference**
Lowest effect level	Level that can be tolerated by the majority of benthic organisms	Field data on benthic communities	6	0.6	16	16	120	Persaud et al., 1991
Threshold effect level	Concentration below which toxicity is rarely observed	Laboratory toxicity tests on aquatic invertebrates using field-collected sediment	13	0.7	41	24	110	Ingersoll et al., 1996
Threshold effect level	Concentrations that are rarely associated with adverse biological effects	Compiled results of modeling, laboratory, and field studies on aquatic invertebrates and fish	5.9	0.596	35.7	18	123	Smith et al., 1996
Minimal effect threshold	Concentration at which minimal effects are observed on benthic organisms	Field data on benthic communities	7	0.9	28	35	150	Environment Canada, 1992
Effects range low[a]	Concentration below which adverse effects would be rarely observed	Field data on benthic communities and spiked laboratory toxicity test data	33	5	70	30	120	Long and Morgan, 1991
Threshold effect level	Concentration below which adverse effects on survival or growth are expected to occur only rarely	Laboratory toxicity tests on the amphipod *Hyalella azteca* using field-collected sediment	11	0.58	28	20	98	EPA, 1996
Consensus threshold effect concentration	Concentration below which adverse effects are expected to occur only rarely	Geometric mean of above published effect concentrations	9.79	0.99	31.6	22.7	121	MacDonald et al., 2000

a. Based on data from both freshwater and marine sites.

Table 4.10. Sediment probable effect concentrations (PECs) for freshwater sediment.

			Concentration (mg/kg dry wt)					
Name	**Definition**	**Basis**	**As**	**Cd**	**Cu**	**Ni**	**Zn**	**Reference**
Severe effects level	Level at which pronounced disturbance of the sediment-dwelling community can be expected	Field data on benthic communities	33	10	110	75	820	Persaud et al., 1991
Probable effect level	Concentrations that are usually or always associated with adverse effects	Laboratory toxicity tests on aquatic invertebrates using field-collected sediment	48	3.2	100	33	540	Ingersoll et al., 1996
Probable effect level	Concentrations that are frequently associated with adverse effects	Compiled results of modeling, laboratory, and field studies on aquatic invertebrates and fish	17	3.53	197	36	315	Smith et al., 1996
Toxic effect threshold	Critical concentration above which major damage is done to benthic organisms	Field data on benthic communities	17	3	86	61	540	Environment Canada, 1992
Effects range median[a]	Concentration above which effects were frequently or always observed or predicted among most species	Field data on benthic communities and spiked laboratory toxicity test data	85	9	390	50	270	Long and Morgan, 1991
Probable effect level	Concentration above which adverse effects on survival or growth are expected to occur frequently	Laboratory toxicity tests on the amphipod *Hyalella azteca* using field-collected sediment	48	3.2	100	33	540	EPA, 1996
Consensus probable effect concentration	Concentration above which harmful effects on sediment-dwelling organisms were expected to occur frequently	Geometric mean of above published effect concentrations	33.0	4.98	149	48.6	459	MacDonald et al., 2000

a. Based on data from both freshwater and marine sites.

4.4.3 Injury determination approaches

The evaluation approach for assessing injury to sediments is anticipated to be similar to the approach described for surface water. Each of the injury definitions identified in Section 4.4.2 consists of several components. Table 4.11 summarizes the components of each definition and the approaches that may be taken in assessing each component.

Table 4.11. Components of relevant sediment injury definitions.

Injury definition	Definition components	Evaluation approach
Biological resources injured when exposed to sediments [43 CFR § 11.62(b)(v); 11.62(e)(11)]	Biological resources are injured when exposed to surface water/sediments.	Compare sediment concentrations to consensus probable effect concentrations (PECs) and consensus threshold effect concentrations (TECs). Determine whether sediment concentrations have caused a shift in benthic communities.

For example, an initial review of existing data suggests exceedences of the consensus PECs for arsenic, nickel, and copper at locations downstream of the mine (Figures 4.10, 4.11, and 4.12). The patterns observed in sediment metal concentrations are related to the pH of surface water. For example, arsenic concentrations in sediment are highest in sediment in Leviathan Creek, because arsenic precipitates out of surface water at a relatively low pH. Concentrations of copper, and nickel in sediment are higher in Bryant Creek than in Leviathan Creek, because these metals will not precipitate out of surface water at the low pH levels measured in Leviathan. As pH increases with dilution in Bryant Creek, these metals precipitate to sediments.

Sediment injuries to benthic macroinvertebrates will also be assessed by evaluating the effects of hazardous substances in sediments on benthic macroinvertebrate communities. A preliminary review of these data is presented in Section 4.6.

4.4.4 Pathway evaluation

A preliminary evaluation of pathways from discharge sources to sediment resources in the assessment area suggests that pathways include direct discharges of hazardous substances to surface water, soil runoff, and groundwater transport (Figure 4.13).

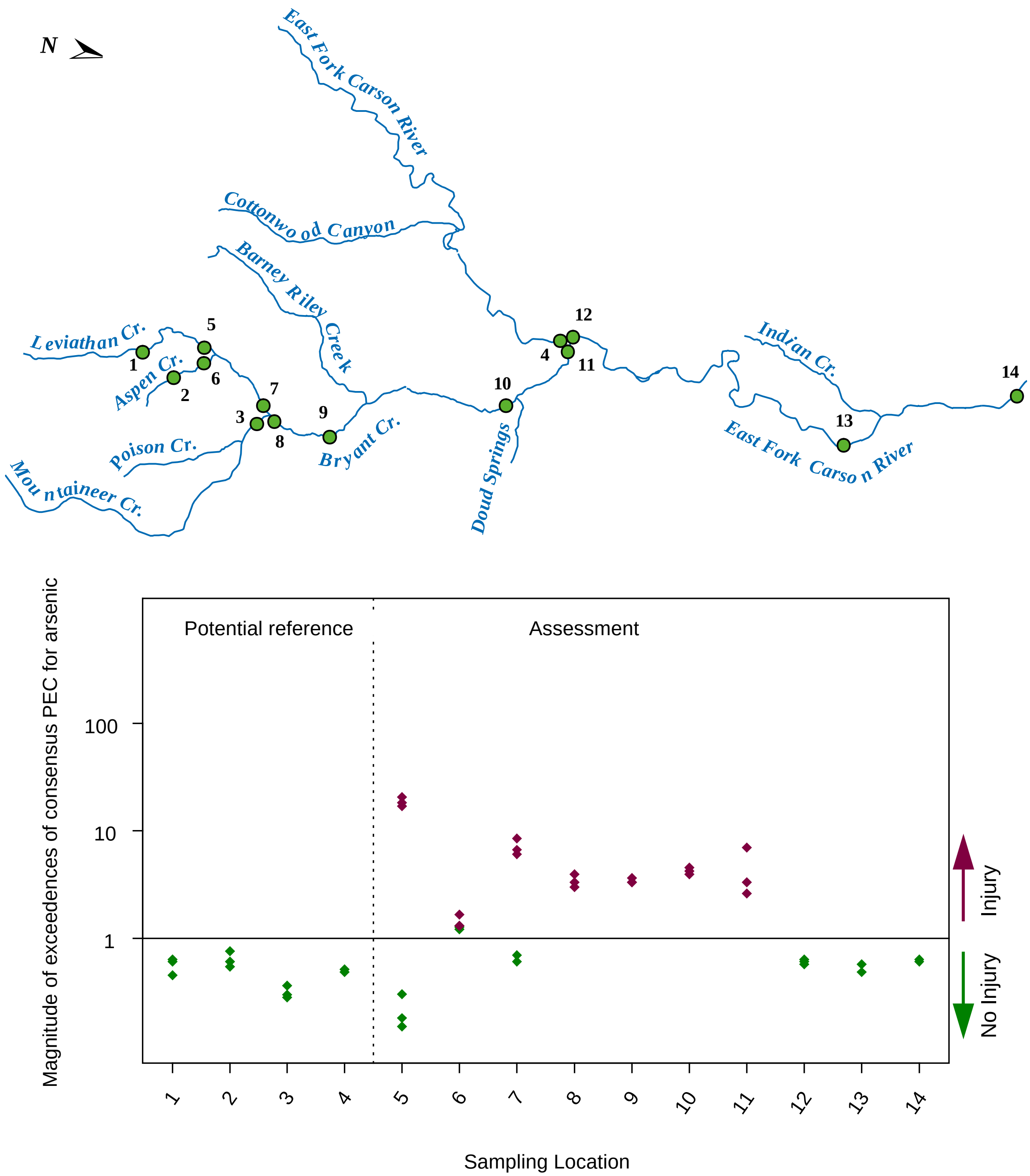


Figure 4.10. Magnitude of exceedences of consensus PEC for arsenic in sediments at 14 sites in the Leviathan-Bryant Creek watershed and the East Fork Carson River. Magnitude of exceedence calculated as concentration of arsenic in sediment divided by PEC.

Source: Thomas and Lico, 2000.

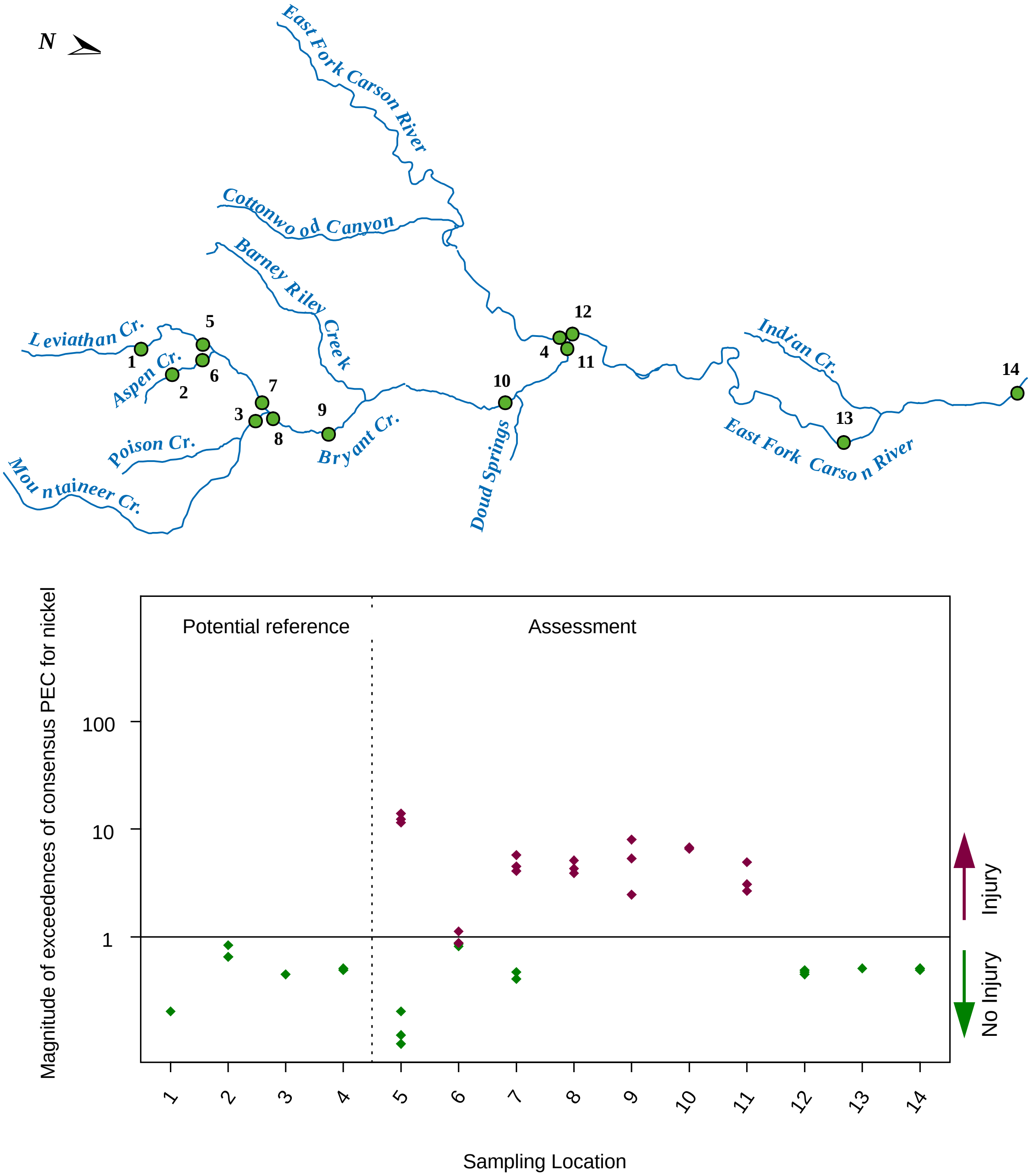


Figure 4.11. Magnitude of exceedences of consensus PEC for nickel in sediments at 14 sites in the Leviathan-Bryant Creek watershed and the East Fork Carson River. Magnitude of exceedence calculated as concentration of nickel in sediment divided by PEC.

Source: Thomas and Lico, 2000.

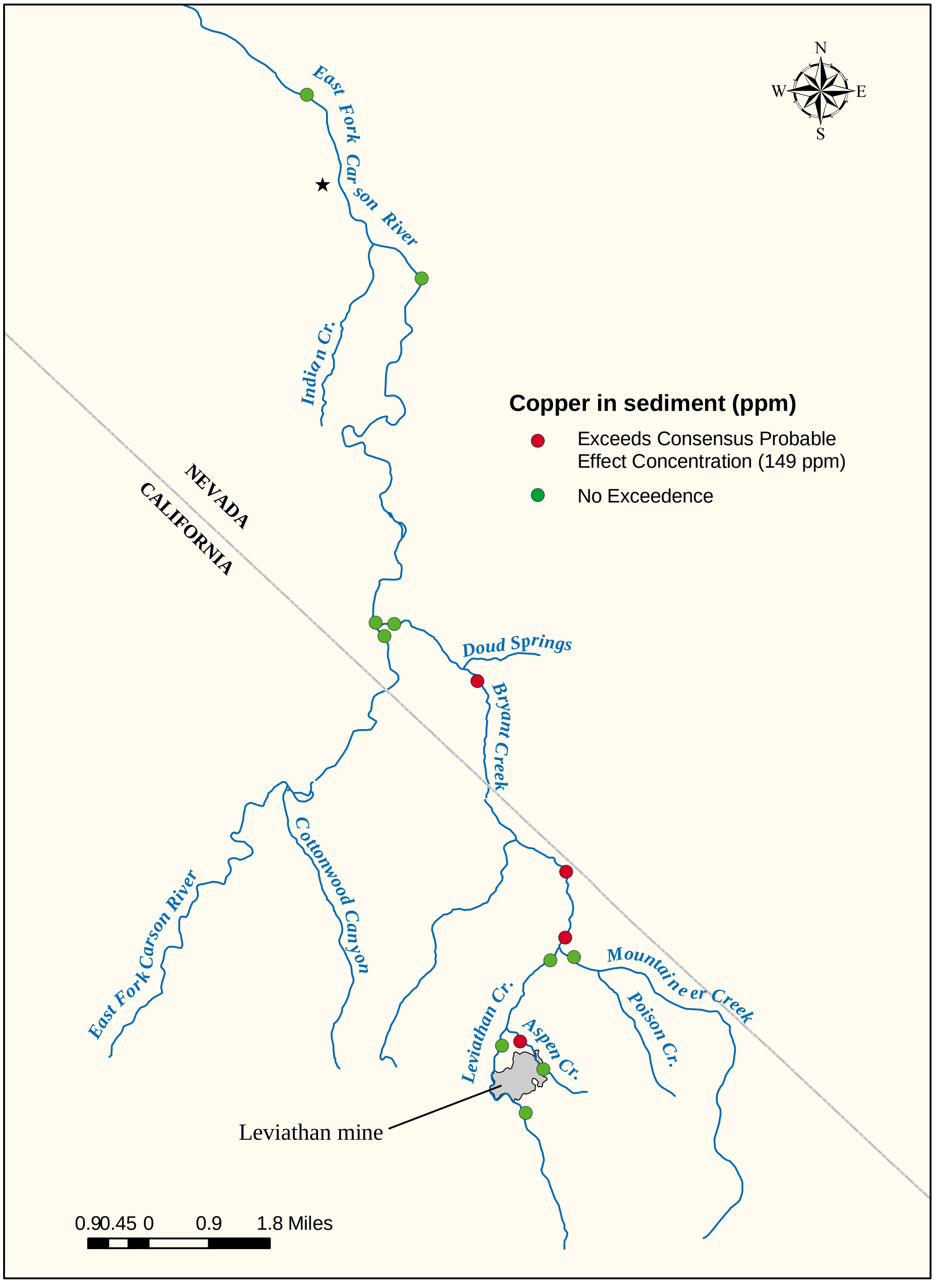


Figure 4.12. Locations within the assessment area where sediment samples exceed the PEC for copper.

Source: Thomas and Lico, 2000.

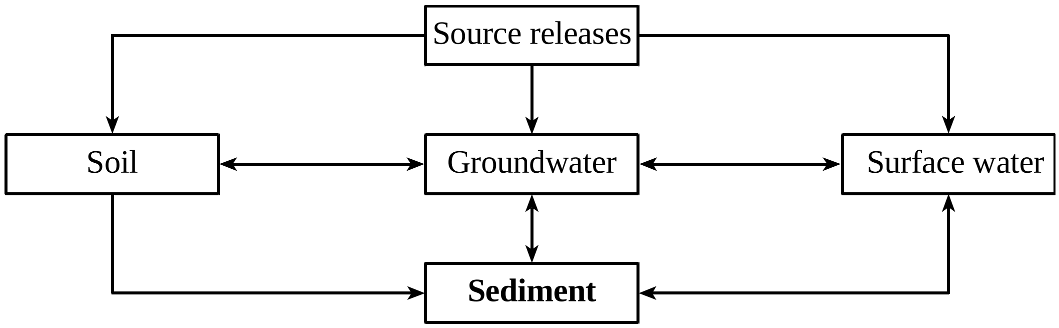


Figure 4.13. Potential sediment exposure pathways.

For example, sediments may have been exposed to concentrations of hazardous substances by historical dumping of mine wastes in the creeks. Surface erosion, mass wasting of tailings and waste piles, and naturally occurring erosion of the streambed and banks may also have contaminated surface water and groundwater, which eventually may have exposed sediments to hazardous substances.

The Trustees anticipate using existing data to demonstrate "the presence of the . . . hazardous substances in sufficient concentrations in the pathway resource" [43 § 11.63(a)(2)].

4.4.5 Injury quantification approaches

Similar to the injury quantification approach described for surface water in Section 4.3.6, quantification of injuries to sediment resources will include evaluation of:

- the spatial extent of injuries throughout the assessment area
- the temporal extent of injuries throughout the assessment area.

GIS platforms may be used to facilitate spatial quantification using the database prepared in the Phase I assessment. A preliminary evaluation of available copper sediment data indicated that copper concentrations in sediments as far downstream from the mine as Bryant Creek near Doud Springs have exceeded the consensus PEC of 149 ppm (Figure 4.12).

4.5 Groundwater Resources

Initial review of existing data suggests that groundwater resources of the assessment area may have been injured as a result of releases of hazardous substances from mining and mineral processing operations at the mine as well as subsequent operations associated with attempts to contain, treat, or otherwise mitigate such releases. This section presents a summary of proposed approaches to evaluate these groundwater injuries.

4.5.1 Data sources

Two documents present data on groundwater resources in the assessment area:

- Hammermeister and Walmsley, 1985
- SRK Consulting, 1999.

From 1981 to 1983, the USGS collected groundwater field data, including pH, water temperature, specific conductance, and major cations and anions from test holes drilled around the mine (Hammermeister and Walmsley, 1985). In 1998, SRK Consulting collected groundwater samples from 15 new wells drilled near the mine. Laboratory analysis included major ion and metal chemistry (SRK Consulting, 1999).

4.5.2 Injury definitions

Based on initial review of existing data, the relevant NRDA regulatory definitions for the evaluation of injuries to groundwater resources include the following:

- Concentrations and duration of hazardous substances in excess of drinking water standards as established by Sections 1411-1416 of the SDWA, or by other federal or state laws or regulations that establish such standards for drinking water, in groundwater that was potable before the release [43 CFR § 11.62(c)(1)(i)].

- Concentrations and duration of hazardous substances sufficient to have caused injury to surface water, when exposed to groundwater [43 CFR § 11.62(c)(1)(iv)].

In addition to the above injury definition, an injury to groundwater resources may result from concentrations and duration of hazardous substances, in excess of baseline conditions, sufficient to cause a loss of services provided by groundwater resources to the general public in addition to unique service losses to members of the Washoe Tribe. Such loss of services may result from health risks posed by groundwater in conjunction with uses of other resources in the assessment area which have been exposed to hazardous substances. Loss of services may also result from perception of contamination of groundwater resources.

Although this latter definition is not listed in the NRDA Regulations [43 CFR § 11.62(c)(1)(i); 11.62(c)(1)(iv)], they do not forbid the use of other injury definitions [43 CFR § 11.11]. Since loss of services provided by resources may be used to determine the amount of damages, if services are lost because of the release of hazardous substances, even if no other definitions of injury are met, the resources should be considered injured.

4.5.3 Injury determination approaches

Based on the injury definitions described in Section 4.5.2, the Trustees anticipate assessing groundwater injuries using an approach similar to that described for surface water and sediment resources. The evaluation will include identifying committed uses and potability of groundwater resources, concentrations and duration of hazardous substances in groundwater, and exceedences of state or federal drinking water standards (see Tables 4.7 and 4.8).

Evaluation of baseline conditions will include consideration of the influence of natural weathering of mineralized deposits and processes that result from historical and ongoing nonmining-related human activities in the assessment area.

In addition, evaluation of groundwater injuries will include consideration of injuries to surface water from numerous springs and seeps emanating from the toe of the overburden piles and flowing directly into Leviathan and Aspen creeks (e.g., channel underdrain, Delta Seep, Aspen Seep; EPA, 2000b). The trustees may evaluate off-site groundwater if data indicate potential injury.

A preliminary review of the available groundwater data suggests that certain groundwater resources may be injured. For example, several groundwater samples collected at the mine in 1998 exceed the SDWA MCL of 50 µl/L for arsenic (Figure 4.14).[2]

4.5.4 Pathway evaluation

The mobility of hazardous substances in aquifers is a function of hydrodynamic and biogeochemical processes and conditions, including recharge locations, infiltration rate, hydraulic gradient, groundwater velocity, and flow patterns, discharge locations, permeability, solubility, precipitation, adsorption, desorption, oxidation/reduction, and other reactions. In the assessment area, infiltration of precipitation and snowmelt through sources of contamination in the unsaturated zone, rising of capillary groundwater to sources of contamination in the unsaturated zone, inundation and leaching of source materials in the saturated zone, metallic sulfides oxidation, and flow of contaminated stream water to alluvial groundwater during high flow may all be mechanisms by which groundwater becomes exposed to hazardous substances from mining (Figure 4.15).

2. Although the EPA approved a new MCL for arsenic of 10 µg/L in 2001, this standard will not go into effect until January 2006.

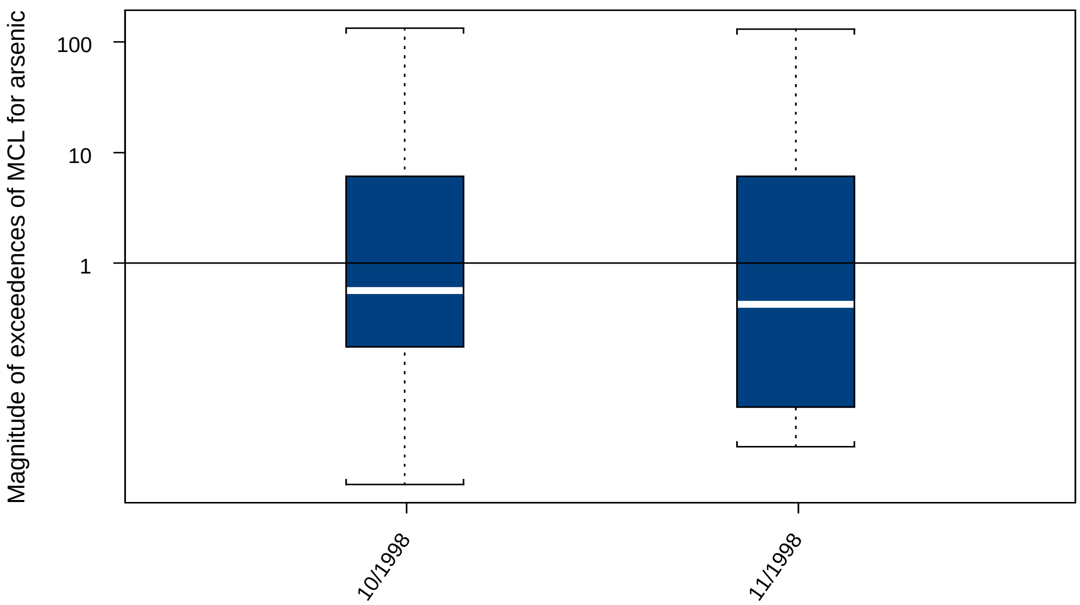


Figure 4.14. Magnitude of exceedences of MCL for arsenic measured in 13 groundwater samples collected near the mine in October 1998 and 14 groundwater samples collected in November 1998. Box-whisker plots represent the median, the range, and the interquartile range.

Source: SRK Consulting, 1999.

4.5.5 Injury quantification approaches

Quantification of injuries to groundwater resources may include evaluation of:

- the spatial extent of injured groundwater within the assessment area
- the volumetric extent of injured groundwater
- the temporal extent of injuries throughout the assessment area, including the yield (or flux) of injured groundwater.

GIS platforms may be used to facilitate spatial quantification of groundwater data for which coordinates are available. For example, a preliminary evaluation of available arsenic groundwater data indicated that arsenic concentrations in groundwater collected from several wells at the mine exceed the MCL for arsenic (Figure 4.16).

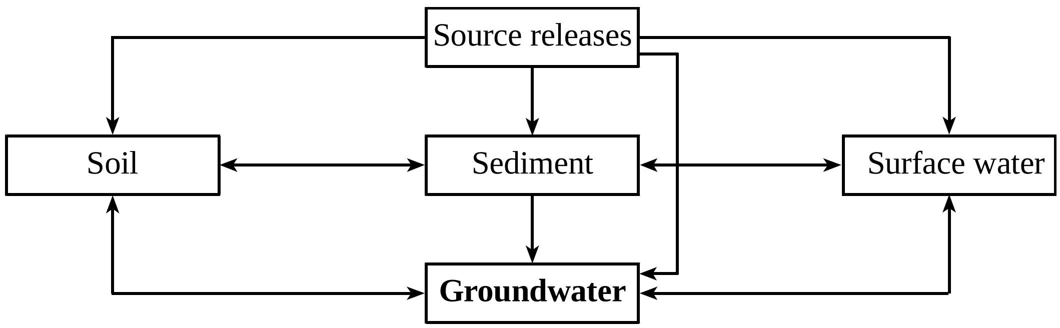


Figure 4.15. Representative groundwater exposure pathways.

4.6 Aquatic Biota

Aquatic resources of the assessment area include fish, benthic macroinvertebrates, and crayfish of the Leviathan-Bryant Creek watershed and East Fork Carson River.

Streams of the Leviathan-Bryant Creek watershed and East Fork Carson River contain several fish species, including Lahontan cutthroat trout (*Oncorhynchus clarki henshawi*), rainbow trout (*Oncorhynchus mykiss*), brown trout (*Salmo trutta*), brook trout (*Salvelinus fontinalis*), mountain whitefish (*Prosopium williamsoni*), mountain sucker (*Catostomus platyrhynchus*), and speckled dace (*Rhinichthys osculus*) (Lehr, 2000). The Lahontan cutthroat trout, a federally listed threatened species under the Endangered Species Act, has been observed in the Leviathan Creek (Lehr, 2000). Furthermore, Mountaineer Creek is listed as a potential reintroduction site for the Lahontan cutthroat trout (Lehr, 2000). Benthic macroinvertebrates characteristic of the watershed include *Baetis* spp., *Corynoneura lobata* spp., *Eukiefferiella clarimpennis* spp., and *Chelifera* spp. (Herbst, 2000).

Initial review of existing data suggests that aquatic biota resources of the assessment area may have been injured as a result of releases of hazardous substances from mining and mineral processing operations at the mine as well as subsequent operations associated with attempts to contain, treat, or otherwise mitigate such releases. This section presents a summary of proposed approaches to evaluate these biota injuries.

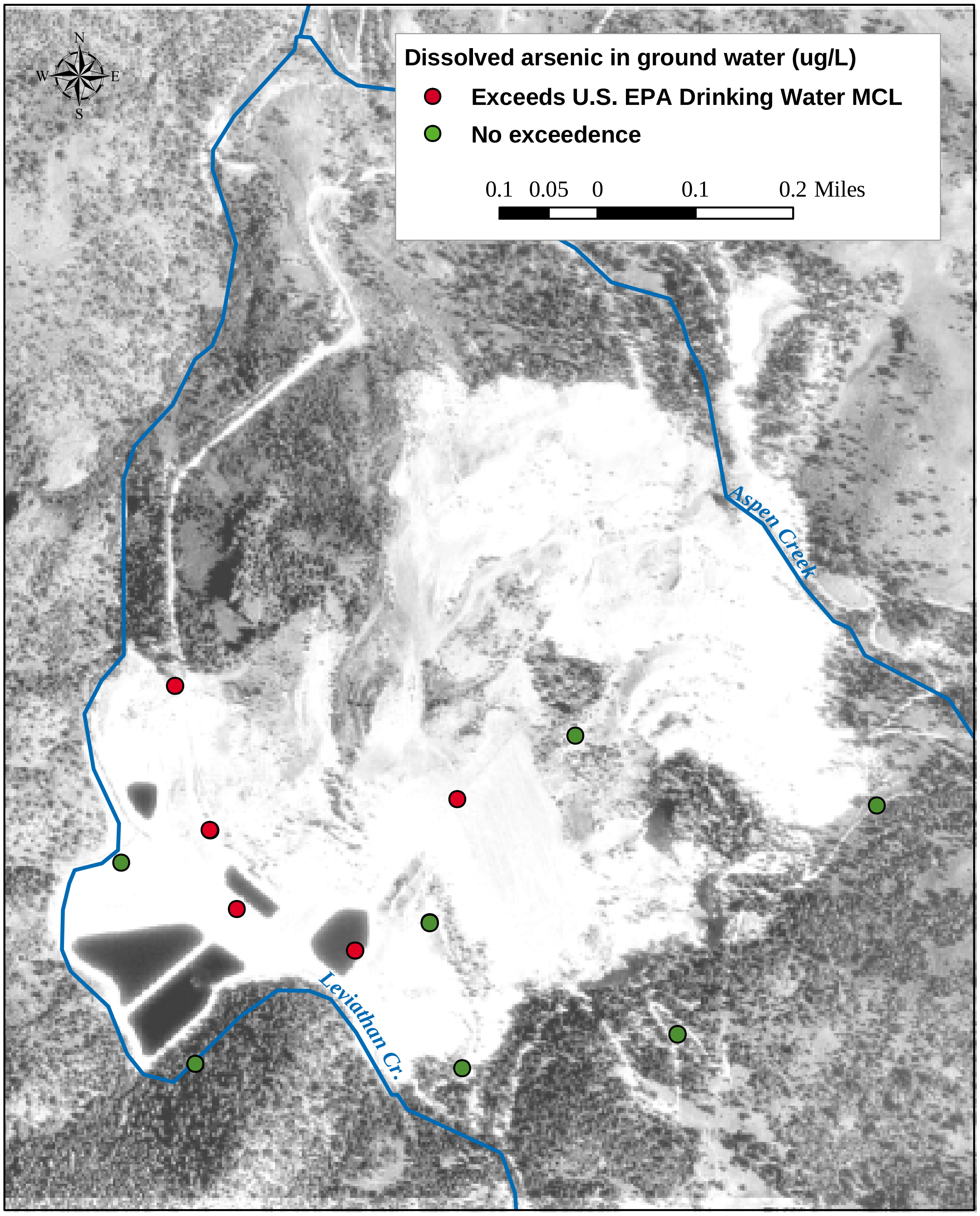


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Figure 4.16. Locations at the mine where groundwater samples were taken for arsenic.

Source: SRK Consulting, 1999.

4.6.1 Data sources

Several sources of site specific data on aquatic biota are available. These sources, listed in order of the actual sampling dates of the data they contain, include:

- Lawrence, 1998
- Thompson and Welsh, 1999
- ENSR, 1999
- Herbst, 1995
- Herbst, 1997
- Herbst, 2000
- Thompson and Welsh, 2000
- Schoen et al., 1995
- Lehr, 2000
- Various Authors, 1969.

In 1992, USGS sampled metal concentrations in crayfish at several locations in the Carson River downstream of Markleeville (Lawrence, 1998). Six years later, Thompson and Welsh (1999) collected aquatic insect samples at two locations upstream of the mine and nine locations downstream of the mine to measure whole-body concentrations of several metals, including arsenic, cadmium, chromium, nickel, and zinc. ENSR (1999) collected benthic macroinvertebrates at several locations upstream and downstream of the mine to characterize the benthic macroinvertebrate communities at each of the sample locations. In 1995, 1997, and 2000, Herbst (1995, 1997, 2000) conducted bioassessment sampling of invertebrates upstream of the mine and at different locations downstream of the mine. Benthic data were evaluated for species richness, density, community, and shifts. Thompson and Welsh (2000) conducted surface water toxicity tests on the waterflea species *Ceriodaphnia dubia*.

These sources provide data on concentrations of hazardous substances in benthic macroinvertebrates as well as results of toxicity studies conducted at locations upstream and downstream of the mine.

In addition, both fish population and fish toxicity data are available. Early toxicity testing with cutthroat trout and rainbow trout was performed in January and July 1958 at different locations downstream of the mine (Schoen et al., 1995). In 1969, sections of the Leviathan, Mountaineer, and Bryant creeks were electrofished to monitor fish populations (Schoen et al., 1995). In October 1998, mountain whitefish were collected in three East Fork Carson River locations to obtain liver and muscle tissue samples (Thompson and Welsh, 2000); in 1999, Thompson and Welsh (2000) conducted surface water toxicity tests on juvenile rainbow trout. In 2000, Lehr (2000) sampled the fishery resources of the Leviathan-Bryant Creek watershed and East Fork Carson River to determine distribution, composition, density, and biomass.

These sources provide data on concentrations of hazardous substances in fish as well as results of toxicity studies conducted at locations upstream and downstream of the mine.

4.6.2 Injury definitions

Based on an initial review of existing data, the relevant NRDA regulatory definitions for the evaluation of injuries to aquatic biota resources:

- Concentrations of a hazardous substance sufficient to cause the biological resource or its offspring to have undergone at least one of the following changes in viability: death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions (including malfunctions in reproduction), or physical deformations [43 CFR § 11.62(f)(1)(i)].

In addition to the above definition, an injury to wildlife resources may result from concentrations and duration of hazardous substances, in excess of baseline conditions, sufficient to cause a loss of services provided by aquatic biota resources to the general public in addition to unique service losses to members of the Washoe Tribe. Such loss of services may be the result of the health risk posed by the use of aquatic biota resources, in and of itself, or the cumulative health risk in conjunction with uses of other resources in the assessment area that have been exposed to hazardous substances. Loss of services may also result from perception of contamination of aquatic biota resources.

Although this definition is not listed in the NRDA regulations [43 CFR § 11.62(f)(1)], the regulations do not forbid the use of other injury definitions [43 CFR § 11.11]. Since loss of services provided by resources may be used to determine the amount of damages, if services are lost because of the release of hazardous substances, even if no other definition of injury is met, the resource should be considered injured since the services it provides have been lost.

4.6.3 Injury determination approach

Fish

Injuries to fish may include death [43 CFR § 11.62 (f)(4)(i)], as confirmed by laboratory toxicity testing [43 CFR § 11.62 (f)(4)(i)(E)], behavioral avoidance [43 CFR § 11.62 (f)(4)(iii)(B)], and physiological malfunctions, including effects on growth [43 CFR § 11.62 (f)(4)(v)].

Several approaches available to evaluate these injuries are presented below.

Comparison of toxicity thresholds with water quality data

As discussed in Section 4.2, several agencies have developed ALC for the protection of aquatic life. An initial review of the data suggested that ALC exceedences were measured in the assessment area downstream of mining activity (Figures 4.2 to 4.4). Exceedences of ALC can be used as a screening level indication of toxicological injuries to fish. This initial assessment will be supplemented with an evaluation of toxicological thresholds derived from the literature. In developing toxicological thresholds, the Trustees will consider test species (to ensure that thresholds are based on testing with species with sensitivity similar to that of fish species in the assessment area) as well as site-specific water quality conditions that may influence toxicity (e.g., hardness, calcium concentration, pH, dissolved organic carbon, alkalinity).

The Trustees will assess injuries by comparing measured water quality conditions with the literature-derived injury thresholds.

Site-specific toxicity tests

The literature-based assessment described above will be supplemented by examining site-specific toxicity data. Site-specific toxicity data include the results of tests conducted on water collected from areas downstream and upstream of mining activities. Several of these tests conducted in the assessment area have suggested that water from areas downstream of mining activity is toxic to fish.

For example, in 1958, investigations were undertaken to determine the toxicity of the water downstream of the mine (Various authors, 1969). Laboratory fish toxicity tests as well as caged fish bioassays were conducted and showed that the waters downstream of the mine were toxic to fish (Various authors, 1969).

Another series of site-specific acute and chronic toxicity tests was conducted by Thompson and Welsh (2000). Juvenile rainbow trout (*Oncorhynchus mykiss*) were exposed to full strength stream water collected from different locations in the Leviathan-Bryant Creek watershed, stream water diluted with laboratory control water, or laboratory control water for 96 hours. The endpoint for the acute tests was organism mortality. The results of this study are presented in Figures 4.17 to 4.18. Water collected in Leviathan Creek downstream of the mine and in Bryant Creek downstream of Leviathan Creek was acutely toxic to juvenile rainbow trout, whereas all fish survived in water collected from reference sites in Aspen Creek, Mountaineer Creek, and the East Fork Carson River (Figure 4.17).

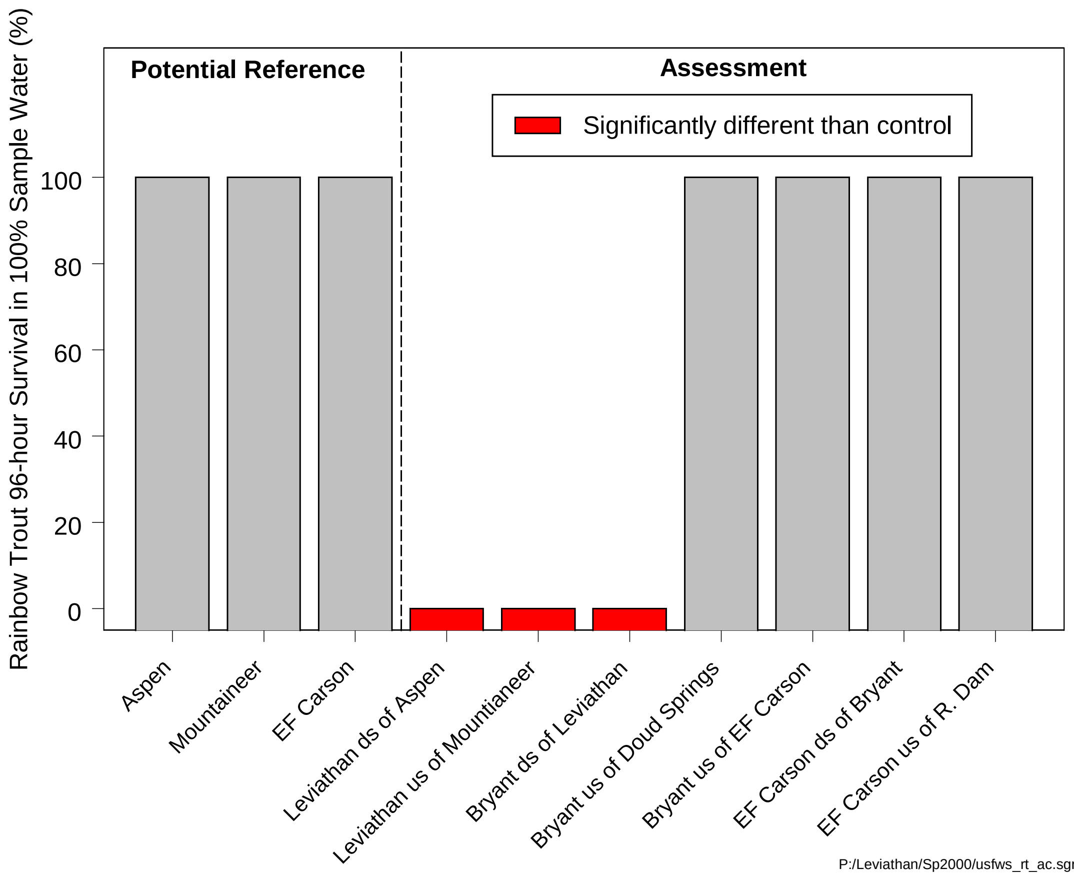

Figure 4.17. Percent survival of juvenile rainbow trout exposed for 96 hours to water sampled from potential reference and assessment sites.

Source: Thompson and Welsh, 2000.

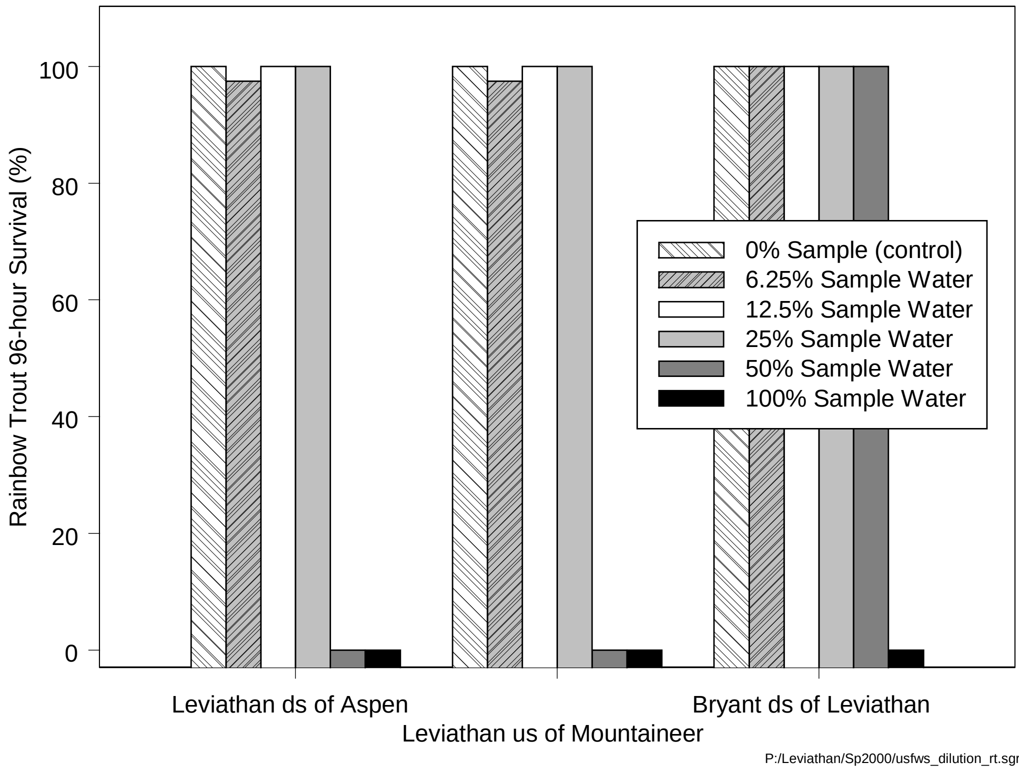

Figure 4.18. Percent survival of juvenile rainbow trout in dilutions of sample water from sites in Leviathan Creek and Bryant Creek where a significant reduction was observed in undiluted sample water.

Source: Thompson and Welsh, 2000.

Sample water from the two assessment sites in Leviathan Creek was also acutely toxic to 100% of juvenile rainbow trout when diluted to 50% sample water (Figure 4.18). Dilutions of water collected from Bryant Creek downstream of Leviathan Creek were not acutely toxic to rainbow trout.

Additional toxicity testing was performed by ENSR (1999). Acute and chronic toxicity tests were conducted with 14 water samples collected from Leviathan, Aspen, and Bryant creeks and the East Fork Carson River using rainbow trout and *Ceriodaphnia dubia*. Acute and chronic toxicity was observed in Leviathan and Aspen creeks downstream of the mine.

Evaluation of dietary exposure pathway

Several studies have concluded that the survival and growth of trout can be impaired if they eat contaminated invertebrate prey (Woodward et al., 1994, 1995). Other studies, however, have suggested confounding effects of nutrition and substantially lower toxicity of ingested metals (Mount et al., 1994). To assess the dietary exposure pathway, the Trustees propose to conduct a thorough evaluation of recent literature and studies to determine whether dietary effects thresholds for metals and arsenic can be derived. These effects thresholds would be compared with concentrations of hazardous substances measured in site invertebrates (Thompson and Welsh, 1999) to evaluate injuries by this pathway. In addition, the Trustees will consider, following this literature evaluation, whether supplemental dietary toxicity tests are warranted.

Fish population data

Fish population data can be used to evaluate whether spatial patterns of fish population density and diversity are consistent with potential toxicological effects. To address this question, fish populations in affected stream reaches will be compared to fish populations in reference areas.

Lehr (2000) sampled the fishery resources of the Leviathan-Bryant Creek watershed and East Fork Carson River to determine distribution, composition, density, and biomass. Numbers of individuals in each segment sampled are presented in Figure 4.19. The data generally show an absence of most species near the mine, and reduced populations in reaches downstream of the mine.

Aquatic invertebrates

Injuries to aquatic invertebrates may include death [43 CFR § 11.62 (f)(4)(i)] and adverse effects on benthic invertebrates community structure.

Several approaches available to evaluate these injuries are presented below.

Comparison of toxicity thresholds with water quality data

As discussed in Section 4.2, published literature will be evaluated to develop injury thresholds for benthic invertebrates.

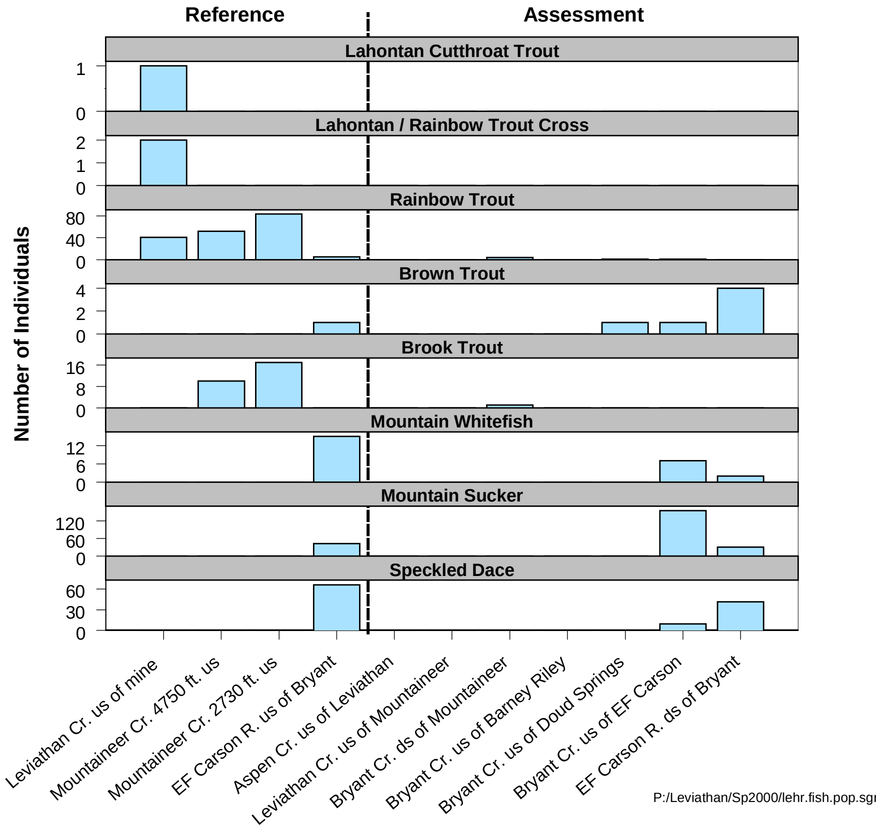

Figure 4.19. Numbers of individuals collected in 1998 at sites in the Leviathan-Bryant Creek watershed and East Fork Carson River.

Source: Lehr, 2000.

Site-specific toxicity tests

As with fish, literature thresholds will be supplemented with site-specific toxicity data. Site-specific toxicity data include the results of tests conducted using water collected from areas downstream and upstream of mining activities. Several of these tests conducted in the assessment area have suggested that water from the mine downstream of mining activity is toxic to benthic macroinvertebrates.

Acute and chronic toxicity tests were conducted by Thompson and Welsh (2000). For the acute test, the waterflea species *Ceriodaphnia dubia* was exposed for 96 hours to full-strength stream water collected from different locations in the Leviathan-Bryant Creek watershed, stream water diluted with laboratory control water, or laboratory control water. The endpoint for the acute tests was mortality. For the chronic tests, the aquatic invertebrate was exposed for 7 days to full-strength stream water, stream water diluted with laboratory control water, or laboratory control water. The endpoint for the chronic tests was reproductive output.

Water was acutely toxic to *Ceriodaphnia dubia* (Figure 4.20) in the same locations that were acutely toxic to juvenile rainbow trout investigated in the same study (see Figure 4.17). There was some mortality in water sampled in Bryant Creek upstream of Doud Springs; however, survival was not significantly different than in control samples.

In dilution tests, sample water from the two assessment sites in Leviathan Creek was also acutely toxic to 100% of *Ceriodaphnia dubia* when diluted to only 25% sample water (Figure 4.21). Dilutions of water collected from Bryant Creek downstream of Leviathan Creek were not acutely toxic.

The results of reproductive tests indicated that water farther downstream in the assessment area was chronically toxic to *Ceriodaphnia dubia* (Figure 4.22; Thompson and Welsh, 2000). Females produced no neonates when exposed to water from Leviathan Creek downstream of Aspen Creek, Leviathan Creek upstream of Mountaineer Creek, and Bryant Creek downstream of Leviathan Creek. In water sampled from Bryant Creek upstream of Doud Springs, females produced an average of 3 neonates per female. In water sampled from Bryant Creek upstream of the East Fork Carson River, only 3.7 neonates were produced per female. In contrast, females produced an average of 20.2, 20.1, and 25.9 neonates each in water from potential reference locations in Aspen Creek, Mountaineer Creek, and East Fork Carson River, respectively.

The results of dilutions are presented in Figure 4.23 for the five locations where significant chronic toxicity was observed in 100% sample water. Water from the two locations in Leviathan Creek diluted to only 6.25% sample water showed a significant reduction in reproduction compared to controls. Water from the three locations in Bryant Creek diluted to 50% showed a significant reduction in reproduction compared to controls

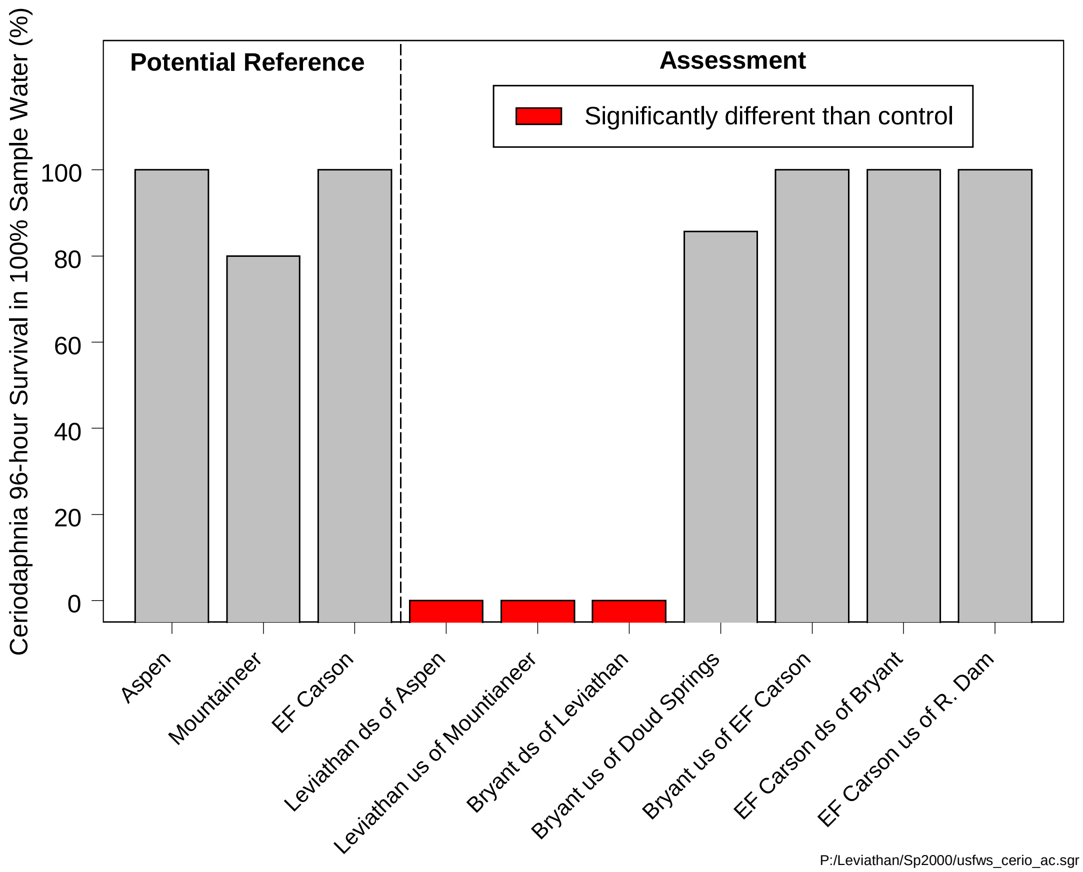

Figure 4.20. Percent survival of *Ceriodaphnia dubia* in water sampled from potential reference and assessment sites.

Source: Thompson and Welsh, 2000.

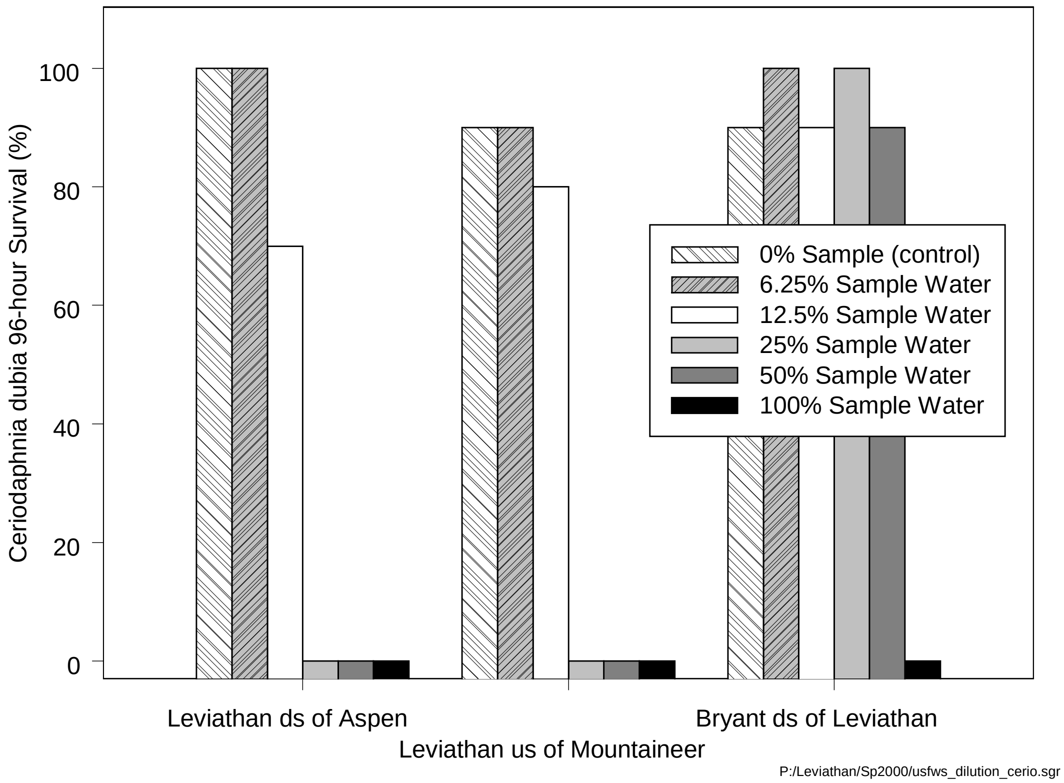

Figure 4.21. Percent survival of *Ceriodaphnia dubia* in increasing dilutions of sample water from sites in Leviathan Creek and Bryant Creek where a significant reduction was observed in undiluted sample water.

Source: Thompson and Welsh, 2000.

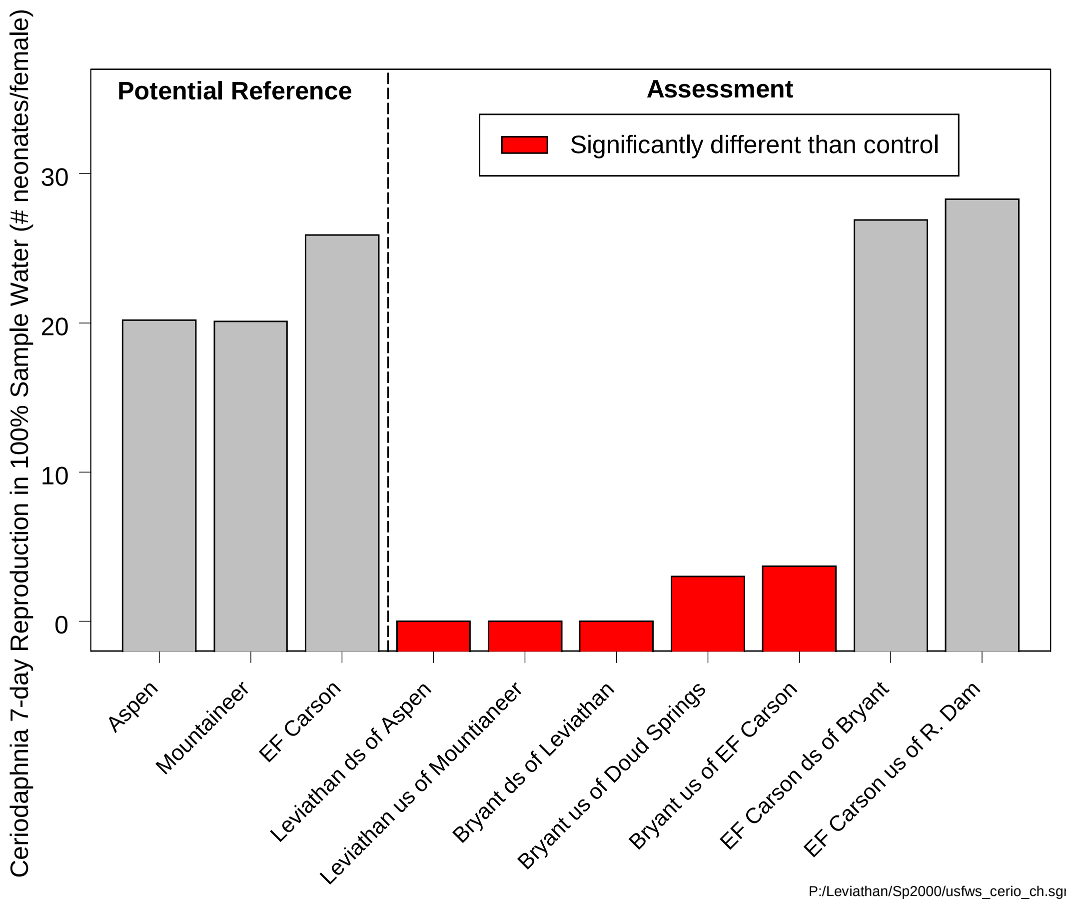

Figure 4.22. Reproductive success of *Ceriodaphnia dubia* in water sampled from potential reference and assessment sites.

Source: Thompson and Welsh, 2000.

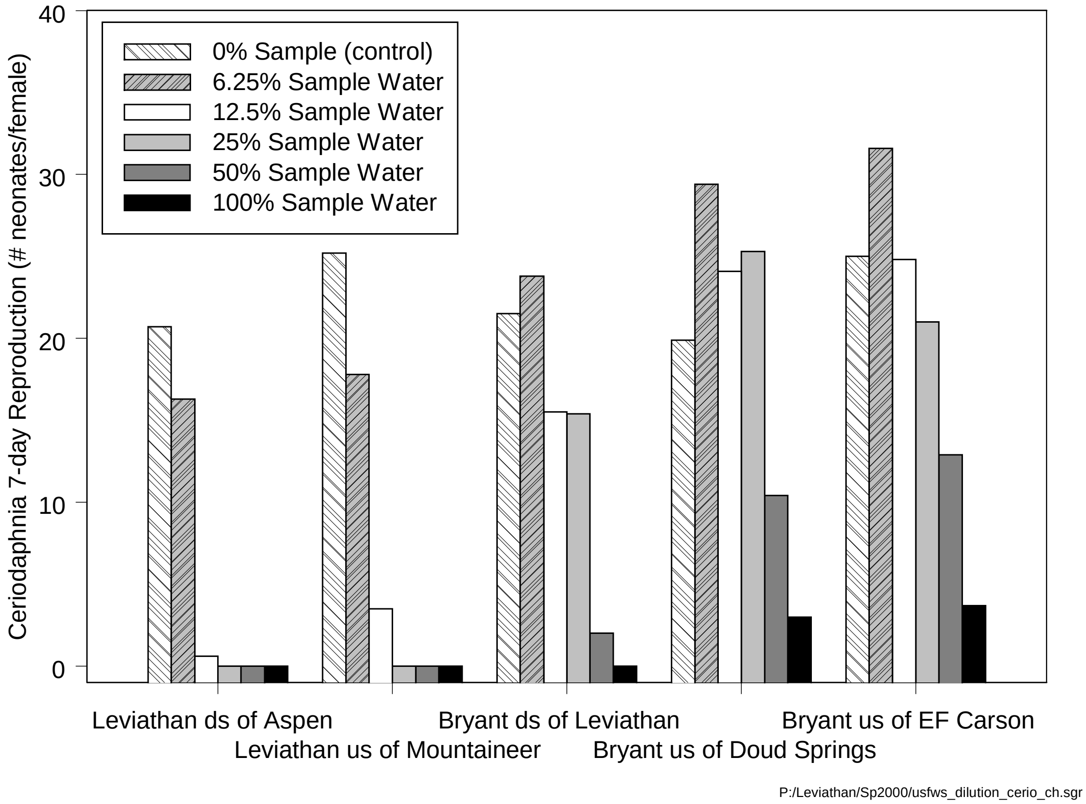

Figure 4.23. Reproductive success of *Ceriodaphnia dubia* in increasing dilutions of sample water from sites in Leviathan Creek and Bryant Creek where a significant reduction was observed in undiluted sample water.

Population and community data

Benthic macroinvertebrates have been used extensively to monitor the effects of metal contamination on aquatic systems. Benthic macroinvertebrates demonstrate individual level responses (e.g., mortality, reduced growth, reduced reproductive fitness) as well as community level responses (e.g., reduced density, reduced species richness, community shift to more tolerant species) to metals. Metals have been shown to be toxic to benthic macroinvertebrates in laboratory and field tests (Clements, 1994; Beltman et al., 1999).

Where metal concentrations are sufficiently elevated, benthic invertebrates may be absent or their abundance greatly reduced (Clements, 1991). Where metal concentrations do not eliminate the community, however, measures of taxa richness (e.g., total number of taxa present) or abundance of metal-sensitive taxa provide the most sensitive and reliable measure of community level effects (Beltman et al., 1999; Carlisle and Clements, 1999). Invertebrate taxa richness is reduced by exposure to metal, because metal-sensitive species are eliminated, and since many mayfly species are sensitive to metal contamination, a reduction in the number of mayfly species presents an effective and reliable measure of metal impacts on benthic macroinvertebrate communities (Kiffney and Clements, 1994).

In the assessment area, several aquatic invertebrate community studies have been conducted to assess the impacts of the mine (e.g., Herbst, 1995, 1997; ENSR, 1999; Herbst, 2000). Reductions in diversity of aquatic invertebrates were observed in all the studies downstream of the mine. Figure 4.24 shows taxa richness at several sites upstream and downstream of the mine in the spring and fall of 1999. Taxa richness is lower by a factor of three in Leviathan and Aspen creeks downstream of the mine compared to potential reference sites. From downstream of the confluence of Aspen Creek with Leviathan Creek, taxa richness steadily increases with distance from the mine.

The Trustees propose using changes in taxa richness, in percentages of mayflies compared to total benthic macroinvertebrates, or in mayflies species richness as indicators of invertebrate community injuries.

4.6.4 Pathway evaluation

As per DOI regulations, pathways may be determined by demonstrating “the presence of hazardous substances in sufficient concentrations in the pathway resource or by using a model that demonstrates that the conditions existed . . . such that the route served as a pathway” [43 CFR § 11.63(a)(2)].

A preliminary evaluation of exposure pathways to aquatic resources in the assessment area suggests that pathways include direct exposure through physical contact with hazardous substances in surface water and sediment as well as indirect exposure through food chain processes (Figure 4.25). Food chain processes represent a significant pathway of exposure to aquatic vertebrates. Elevated concentrations of metals in invertebrates and fish will be used to confirm that exposed water and sediments are a pathway to invertebrates and fish throughout the assessment area.

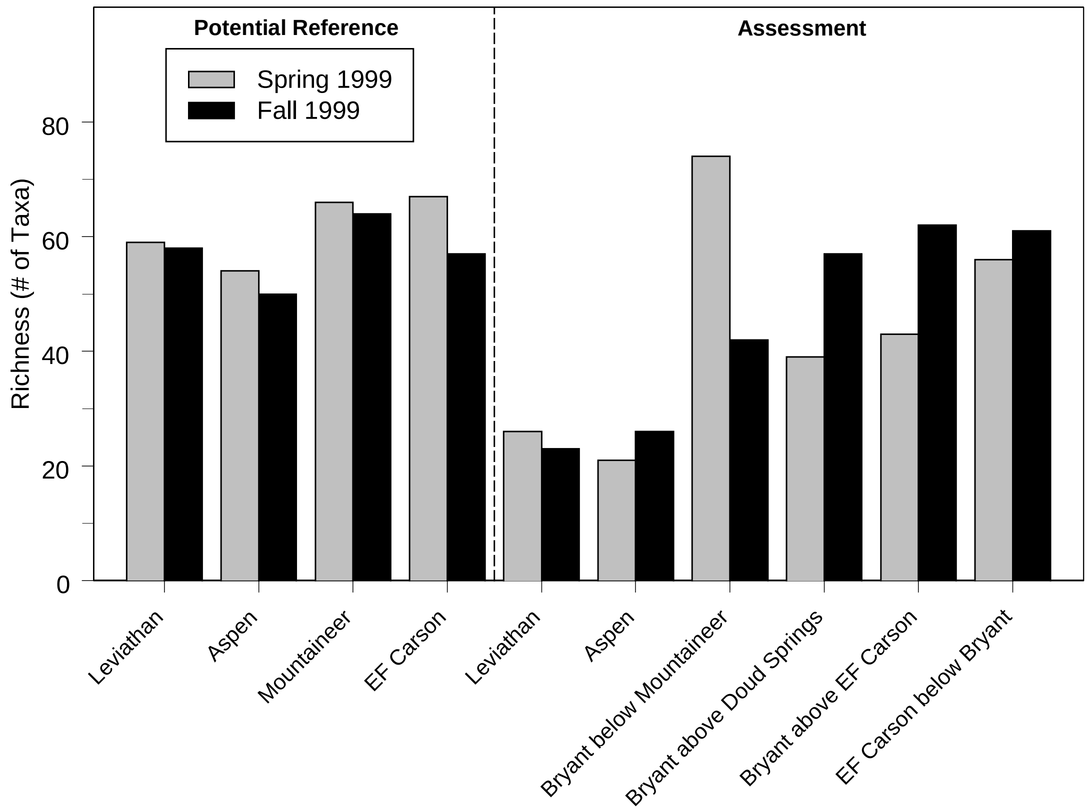

Figure 4.24. Taxa richness at several sites in the Leviathan-Bryant Creek watershed and the East Fork Carson River.

Source: Herbst, 1999.

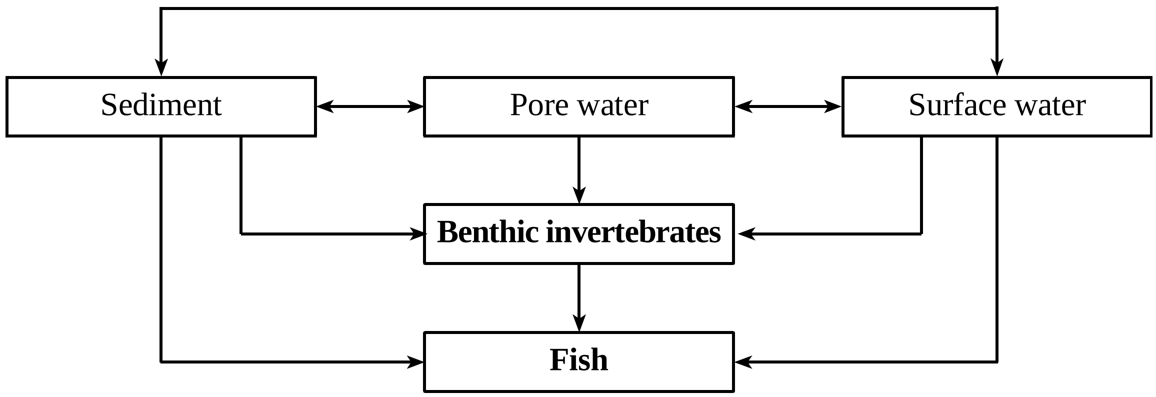

Figure 4.25. Potential biological exposure pathways.

4.6.5 Injury quantification approaches

Quantification of injuries to aquatic biota resources may include evaluation of:

- the spatial extent of injuries throughout the assessment area
- the temporal extent of injuries throughout the assessment area
- the degree of changes in population/community endpoints.

As with other resources, the Trustees will employ a reference location approach in establishing baseline conditions. In addition, the Trustees will consider land uses that may affect aquatic biota. For example, livestock grazing and agricultural water withdrawals (e.g., lower and upper River Ranch diversions) affect the condition of Bryant Creek. These land uses will be considered in evaluating baseline conditions.

4.7 Floodplain Soils

According to DOI NRDA regulations, sediments and soils are considered geologic resources [43 CFR §11.14 (s)]. Because sediments also are considered a component of surface water resources [43 CFR §11.14 (pp)], suspended and bed sediments were addressed in Section 4.4. This section focuses on stream bank floodplain soils. Floodplains, areas of a valley floor adjacent to stream channels, are typically inundated and receive deposits of fine sediment during periods of high stream flow. Soils develop on the floodplain from these sediment deposits. These soils constitute the floodplain soil resource of the Leviathan-Bryant Creek watershed and East Fork of the Carson River.

By their nature, floodplain soils come into contact with surface water and are created by deposited sediment. Additionally, soils have been irrigated with surface water from Bryant Creek. Surface water and sediment in the assessment are contaminated by metals (Sections 3.2 and 3.3). Visual observations of stream banks and floodplain soils in the assessment area suggest that certain areas may have been injured. These considerations provide a rationale for including injuries to floodplain soils, including irrigated soils, as a component of this assessment. This section presents a summary of proposed approaches to evaluate these injuries.

4.7.1 Data sources

No studies of soils from assessment area floodplains have been identified to date. However, two sources of related soils data are available:

- Nelson Laboratories, 1969
- Young, 1970.

Nelson Laboratories (1969) analyzed and evaluated soils at the River Ranch located on the East Fork Carson River irrigated with water diverted from Bryant Creek. Young (1970) analyzed and evaluated soils at the River Ranch irrigated with Bryant Creek water relative to soils irrigated with Cottonwood Creek water. Both studies reported results for pH and metals; the 1969 study also included an analysis of nutrients.

4.7.2 Injury definitions

Based on an initial review of the existing information, the relevant NRDA definitions for the evaluation of injury applicable to geologic resources and thus floodplain soils in the assessment area may include the following [43 CFR §11.62(e)]:

> An injury to the geologic resource has resulted from the . . . release of a hazardous substance if one or more of the following changes in the physical or chemical quality of the resource is measured:
>
> - Concentrations of substances sufficient to raise the negative logarithm of the hydrogen ion concentration of the soil (pH) to above 8.5 . . . or to reduce it below 4.0;
>
> - Concentrations of substances sufficient to have caused injury as defined in paragraphs (b), (c), (d), or (f), of this section to surface water, ground water, air, or biological resources when exposed to the substances.

The presence of hazardous substances on floodplains in the system has the potential to cause or have caused injury to floodplain soils by causing the pH of the soils to be reduced to below 4.0. Additionally, toxic effects of these substances can result in a reduction in riparian vegetation cover and complexity, which in turn may result in deterioration of ecological functions, including but not limited to provision of supporting habitat for dependent biological resources such as wildlife.

In addition to the above definition, an injury to floodplain soil resources may result from concentrations and duration of hazardous substances, in excess of baseline conditions, sufficient to cause a loss of services provided by floodplain soils to the general public in addition to unique service losses to members of the Washoe Tribe. Such loss of services may be the result of the health risk posed by the use of the soil, in and of itself, or the cumulative health risk in conjunction with uses of other resources in the assessment area that have been exposed to hazardous substances. Loss of services may also result from perception of contamination of floodplain soils.

Although this definition is not listed in the NRDA regulations [43 CFR § 11.62(e)], the regulations do not forbid the use of other injury definitions (43 CFR § 11.11). Since loss of services provided by resources may be used to determine the amount of damages, if services are lost because of the release of hazardous substances, even if no other definition of injury is met, the resource should be considered injured since the services it provides have been lost.

4.7.3 Injury determination approaches

It is anticipated that the injury determination for floodplain geologic resources will consist of several components. First, a literature search and review of relevant studies previously conducted in the study area will be performed. Then, if appropriate, field studies to collect soil samples for chemical analysis, laboratory analyses of pH and metals concentrations in soils, and examination of riparian vegetation (see Section 4.8) may be performed.

Table 4.12 summarizes the components of each injury definition and the approaches that may be taken in assessing each component. The following sections briefly summarize the methods that may be associated with the various components of the injury determination.

4.7.4 Additional study

Data from previous studies relevant to floodplain soils within the assessment area or potential reference areas are lacking. No available data demonstrate that assessment area floodplain soils exhibit pH values less than 4.0. However, surface waters with pH values between 2 and 4 have been measured in Leviathan and Bryant creeks, suggesting the possibility of low pH values in

Table 4.12. Components of relevant floodplain soils injury definitions.

Injury definition	Definition components	Evaluation approach
Floodplain soil pH reduced to below 4.0 [43 CFR § 11.62(e)(2)]	Floodplain soils with pH values less than 4.0 are injured.	Determine pH values in floodplain soils.
Baseline exceedence	Floodplain soil resources are injured when concentrations of hazardous substances exceed baseline.	Determine whether concentrations exceed baseline.
	Baseline exceedences cause loss of services to the Washoe Tribe.	Determine whether floodplain soil services have been lost as a result of exceedences.

soils and also sediments. A study at the River Ranch (East Fork Carson River) demonstrated that pasture soils irrigated with water diverted from Bryant Creek had lower pH values than adjacent nonirrigated soils (Nelson Laboratories, 1969). Another study at the River Ranch (Young, 1970, p. 5) demonstrated lower pH values in meadow soils irrigated with Bryant Creek water relative to soils irrigated with Cottonwood Creek water. Although the soil pH was greater than 4.0 for the soils tested, these studies show the potential for low pH surface water to reduce soil pH values, particularly with prolonged exposure.

A literature search will be performed to identify any additional studies with data relevant to the injury assessment. Data found will be reviewed to determine usability in the assessment. Relevant data of suitable quality will be incorporated into the assessment and into work plans for field and laboratory studies.

Based on the results of the literature review, a field sampling program may be designed and implemented to characterize floodplain soils both in the assessment area and in selected reference areas. The program design will be documented in a work plan. Soil samples will be collected from floodplain areas and submitted for chemical analyses. The resulting samples and data will be used to evaluate injury to soils and to quantify the spatial extent of any injury in the floodplains of the assessment area relative to baseline conditions.

A qualified laboratory will be used to analyze any soils. Analyses may include, but not be limited to, pH, sulfate, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, selenium, thallium, and zinc. Analyses for soil nutrient parameters (including but not limited to nitrogen, phosphorous, and potassium) may also be performed. The number of samples analyzed will depend on the final sample design and will be documented in the work plan. The analytical program will conform and comply with the Quality Assurance Project Plan (QAPP) developed for the NRDA.

4.7.5 Pathway evaluation

A preliminary evaluation of pathways from discharge sources to floodplain soil resources in the assessment area suggests that pathways include direct discharges of hazardous substances to surface water, soil runoff, and surface water/sediment transport and deposition (Figure 4.26).

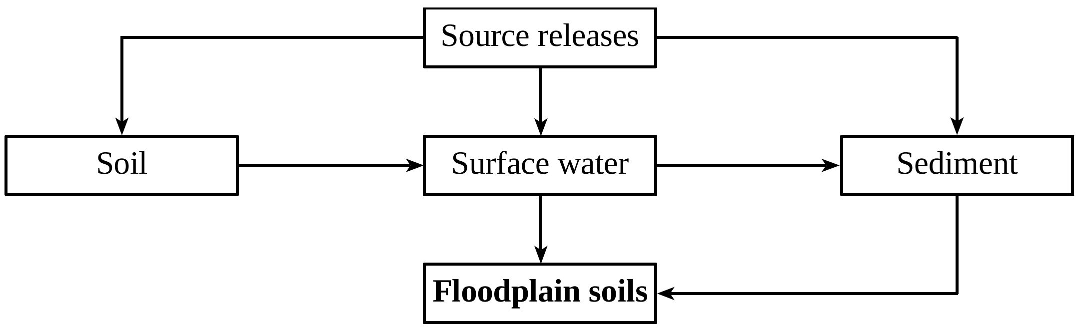

Figure 4.26. Potential floodplain soil exposure pathways.

For example, evaporation ponds receiving acid mine drainage from various springs and seeps have overflowed during the winter and early spring, causing a release of acid mine drainage into Leviathan Creek (Herbst, 2000, p.1). Surface erosion of contaminated soils in the mine area may have exposed sediments to hazardous substances. Transport and deposition of contaminated sediments may have exposed floodplain soils to hazardous substances. The contaminated soils in turn may constitute an additional pathway to biological resources associated with riparian areas.

4.7.6 Injury quantification approaches

For floodplain soil resources, service reduction quantification will require determination of (1) the surface area of soil with reduced ability to sustain the growth of vegetation from the baseline level [43 CFR §11.71(k)(1)] and/or (2) the surface area of soil with reduced suitability as habitat for biota from the baseline level [43 CFR §11.71(k)(2)].

It is unlikely that sufficient historical data are available to establish baseline conditions (premining) [43 CFR §11.72(c)] for the impacted areas downstream of the mine. Therefore, control or reference areas that are comparable to assessment areas may be used to evaluate baseline conditions [43 CFR §11.72(d)]. Reference areas will be established and evaluated during the field study of floodplain soils.

4.8 Riparian Vegetation Resources

Terrestrial and aquatic plants are addressed as biological resources by the NRDA regulations [43 CFR §11.14 (f))]. Vegetation resources potentially impacted by releases of hazardous substances from the mine area are primarily in the riparian areas of the Leviathan-Bryant Creek watershed and the East Fork of the Carson River. Riparian areas are located between the active stream channels and uplands, which generally coincide with floodplain areas. Riparian vegetation comes into contact with surface water sediments and floodplain soils. Surface water and sediments are contaminated by metals (Sections 3.2 and 3.3), and floodplain soils are likely to be contaminated as well (Section 4.7). Thus, riparian vegetation will be included as a component of this assessment. This section presents a summary of proposed approaches to evaluate injuries to riparian vegetation.

4.8.1 Data sources

Although riparian vegetation appears to be reduced in parts of the assessment area, no studies have been identified that could be used to determine and quantify past, present, and future injuries to these resources.

4.8.2 Injury definitions

The relevant NRDA regulatory definition for the evaluation of injury to biological resources and thus to riparian vegetation resources is found at 43 CFR §11.62(f)(1):

> An injury to a biological resource has resulted from the . . . release of a hazardous substance if concentration of the substance is sufficient to:
>
> - Cause the biological resource or its offspring to have undergone at least one of the following adverse changes in viability: death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions (including malfunctions in reproduction), or physical deformation.

The method for determining injury to a biological resource must be capable of demonstrating a measurable biological response that can satisfy all of the following acceptance criteria:

- The biological response is often the result of exposure to hazardous substances [43 CFR §11.62(f)(2)(i)].

- Exposure to hazardous substances is known to cause this biological response in free-ranging organisms [43 CFR §11.62(f)(2)(ii)].

- Exposure to hazardous substances is known to cause this biological response in controlled experiments [43 CFR §11.62(f)(2)(iii)].

- The biological response measurement is practical to perform and produces scientifically valid results [43 CFR §11.62(f)(2)(iv)].

The presence of hazardous substances in floodplains of the assessment area has the potential to cause or have caused injury to riparian vegetation resources, including aquatic and wetland species, by resulting in significant reduction in riparian vegetation cover and complexity (e.g., through death or physical deformation). These effects in turn may result in deterioration of ecological functions, including but not limited to habitat for dependent biological resources such as wildlife.

In addition to the above definition, an injury to vegetation resources may result from concentrations and duration of hazardous substances, in excess of baseline conditions, sufficient to cause a loss of services provided by riparian vegetation to the general public in addition to unique service losses to members of the Washoe Tribe. Such loss of services may be the result of the health risk posed by the use of plants, in and of itself, or the cumulative health risk in conjunction with uses of other resources in the assessment area that have been exposed to hazardous substances. Loss of services may also result from perception of contamination of riparian vegetation.

Although this definition is not listed in the NRDA regulations [43 CFR § 11.62(f)(1)], the regulations do not forbid the use of other injury definitions [43 CFR § 11.11]. Since loss of services provided by resources may be used to determine the amount of damages, if services are lost because of the release of hazardous substances, even if no other definition of injury is met, the resource should be considered injured since the services it provides have been lost.

4.8.3 Injury determination approaches

Injury to riparian vegetation resources will be determined by measuring and evaluating vegetation cover, community structure, and composition in the assessment area relative to reference areas. Riparian vegetation will be considered injured where these measures demonstrate significant difference relative to reference areas [43 CFR §11.62(f)(1)(i)]. This determination will satisfy the requirements for injury to biological resources as specified under 43 CFR §11.62(f)(2).

Table 4.13 summarizes the components of each injury definition and the approaches that may be taken in assessing each component.

Table 4.13. Components of relevant riparian vegetation injury definitions.

Injury definition	Definition components	Evaluation approach
Biological resources injured when exposed to hazardous substances [43 CFR § 11.62(f)(1)(i)]	Riparian vegetation resources have undergone death or physical deformation.	Evaluate vegetation cover, community structure and composition in the assessment area relative to reference areas.
Baseline exceedence	Riparian vegetation resources are injured when concentrations of hazardous substances exceed baseline.	Determine whether concentrations exceed baseline.
	Baseline exceedences cause loss of services to the Washoe Tribe.	Determine whether riparian vegetation services have been lost as a result of exceedences.

The injury determination for riparian vegetation resources will consist of a review of relevant studies previously conducted in the study area; a review of relevant published literature on the effects of pH and metals on plants and vegetation communities, as well as the uses of riparian resources by the Washoe Tribe and resident wildlife; a review of available aerial photography (both recent and historical) to delineate temporal and spatial trends in the distribution of riparian vegetation; field studies to measure vegetation cover and community structure/composition; and evaluations of the field data to determine injury. The following sections briefly summarize the methods that may be used with the various components of the injury determination.

Previous studies, literature review, and aerial photography review

Data from previous studies relevant to riparian vegetation within the assessment area or potential reference areas are lacking. However, a thorough literature search will be performed to identify any studies with data relevant to the injury assessment. Data found will be reviewed to determine usability in the assessment. Relevant data of suitable quality will be incorporated into the assessment and into the work plan for field studies.

A literature review will be performed to summarize known effects of metals and low pH on riparian resources, including riparian vegetation, riparian habitat, and dependent wildlife. Wildlife use of vegetation will also be reviewed. For example, studies have shown that metals can be concentrated in riparian vegetation through uptake from exposed soils. This vegetation may serve as a food source for dependent wildlife, which may then be exposed to toxic concentrations of these metals, such as cadmium in willows (e.g., Larison et al., 2000, p. 1). In addition, in the tribal injury assessment study (Chapter 5), a literature review will be performed to determine all relevant tribal uses of potentially affected resources. For example, Washoe Tribal members use willows for basket weaving and other purposes (Nevers, 1976), and consume watercress (D'Azevedo, 1986). These literature reviews will help focus the field studies with respect to the characteristics of the assessment area, and will necessarily be completed before finalizing field work plans.

Field vegetation studies

A field program may be designed to characterize community composition and structure at representative locations within the assessment area and in selected reference areas. The program design will be documented in a work plan. In addition, individual species will be tracked during the field studies, in particular those species that are significant with respect to both tribal use and wildlife use, including but not limited to willow, watercress, chokecherry, Sego lily, and wild onion.

4.8.4 Pathway considerations

A preliminary evaluation of pathways from discharge sources to riparian vegetation resources in the assessment area suggests that pathways include direct discharges of hazardous substances to surface water, soil runoff, groundwater, and surface water/sediment transport and deposition (Figure 4.27).

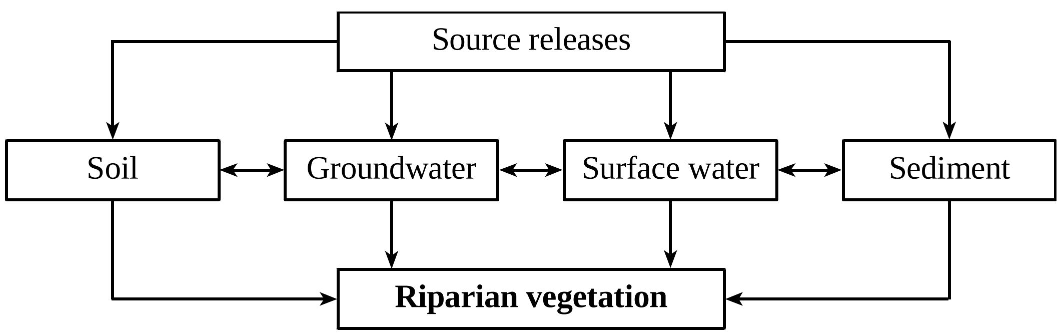

Figure 4.27. Potential exposure pathways for riparian vegetation.

For example, evaporation ponds receiving acid mine drainage from various springs and seeps have overflowed during winter and early spring, causing a release of acid mine drainage into Leviathan Creek (Herbst, 2000, p. 1). Surface erosion of contaminated soils in the mine area may have exposed sediments to hazardous substances. Transport and deposition of contaminated sediments onto the floodplain and incorporation into floodplain soils may have exposed riparian vegetation to hazardous substances. Surface water and groundwater transpired by plants may expose riparian vegetation to hazardous substances through root uptake or surface contact.

4.8.5 Injury quantification approaches

For riparian vegetation resources, service reduction quantification may include determination of differences in populations or habitat/ecosystems between the injured resource and baseline [43 CFR §11.71(l)(1)].

It is unlikely that sufficient historical data are available to establish baseline. Therefore, control or reference areas that are comparable to assessment areas may be used to evaluate baseline [43 CFR §11.72(d)]. Reference areas will be established and evaluated during the field study of riparian vegetation resources.

4.9 Terrestrial Wildlife Resources

Wildlife resources in the assessment area include birds, mammals, reptiles, and amphibians, which are addressed as biological resources by the NRDA regulations [43 CFR §11.14(f)]. Wildlife resources come into contact with surface water, sediments, soils, and riparian vegetation in the assessment area. Surface water and sediments are contaminated by metals (Sections 4.2 and 4.3) and it is likely that floodplain soils and riparian vegetation are also contaminated (Sections 4.7 and 4.8). Wildlife resources may be exposed to contaminated resources through dermal contact or ingestion. This potential exposure provides a rationale for the consideration of wildlife resources as a part of this assessment.

Because of uncertainties regarding the degree of injuries to wildlife, the decision to proceed with injury determination and quantification will depend on the results of injury studies for other resources. Consequently, these sections outline the process by which this decision could be made.

4.9.1 Data sources

Although no wildlife surveys are known for the assessment area, information available for a nearby area (Brown and Caldwell, 1983, Appendix C) documents numerous species, many of which are expected to be present in the assessment area.

4.9.2 Injury definition

The relevant NRDA regulatory definition for the evaluation of injury to biological resources and thus to wildlife resources is found at 43 CFR §11.62(f)(1):

> An injury to a biological resource has resulted from the . . . release of a hazardous substance if concentration of the substance is sufficient to:
>
> - Cause the biological resource or its offspring to have undergone at least one of the following adverse changes in viability: death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions (including malfunctions in reproduction), or physical deformation.

The method for determining injury to a biological resource according to the regulatory definition must be capable of demonstrating a measurable biological response that can satisfy all of the acceptance criteria as specified at 43 CFR §11.62(f)(2) (see Section 4.8.2). Behavioral abnormalities would include avoidance of riparian areas as a result of injury to other resources.

In addition to the above definition, an injury to wildlife resources may result from concentrations and duration of hazardous substances, in excess of baseline conditions, sufficient to cause a loss of services provided by wildlife to the general public in addition to unique service losses to members of the Washoe Tribe. Such loss of services may be the result of the health risk posed by the use of the wildlife, in and of itself, or the cumulative health risk in conjunction with uses of other resources in the assessment area that have been exposed to hazardous substances. Loss of services may also result from perception of contamination of wildlife.

Although this definition is not listed in the NRDA regulations [43 CFR § 11.62(f)(1)], the regulations do not forbid the use of other injury definitions [43 CFR § 11.11]. Since loss of services provided by resources may be used to determine the amount of damages, if services are lost because of the release of hazardous substances, even if no other definition of injury is met, the resource should be considered injured since the services it provides have been lost.

4.9.3 General approach

If sufficient cause for proceeding with injury determination for wildlife resources is found, an initial step would be to determine the feasibility of developing injury studies that are both cost-effective and technically defensible.

Table 4.14 summarizes the components of each injury definition and the approaches that may be taken in assessing each component.

Table 4.14. Components of relevant wildlife injury definitions.

Injury definition	Definition components	Evaluation approach
Biological resources injured when exposed to hazardous substances [43 CFR § 11.62(f)(1)(i)]	Wildlife resources have undergone death, disease, behavioral abnormalities, cancer, genetic mutations, physical malfunctions, or physical deformation.	Evaluate presence and significance of potential pathways before proceeding with injury studies.
Baseline exceedence	Wildlife resources are injured when concentrations of hazardous substances exceed baseline.	Determine whether concentrations exceed baseline.
	Baseline exceedences cause loss of services to the Washoe Tribe.	Determine whether wildlife services have been lost as a result of exceedences.

Demonstration of pathways

Pathways from hazardous substances to wildlife resources should be demonstrated to exist within the assessment area. Potential pathways anticipated are through other injured resources (exposure via ingestion, inhalation, or dermal contact), including but not limited to surface water, floodplain soils, and riparian vegetation (Figure 4.28). Evaluation of pathways to wildlife may include an inventory of wildlife species based in the assessment area and an evaluation of wildlife use of other injured resources. If pathways from other injured resources to wildlife resources were not found to exist, injury determination for wildlife resources would not be pursued.

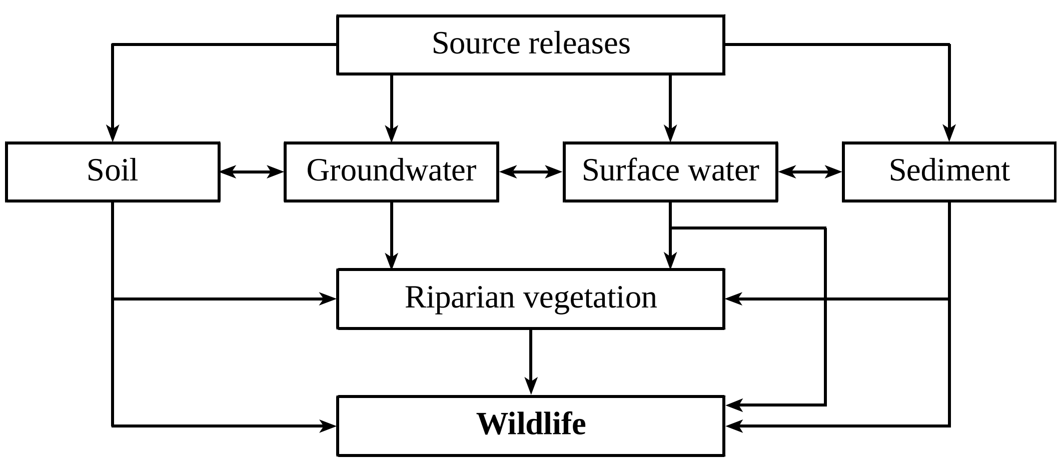

Figure 4.28. Potential exposure pathways for wildlife.

Significance of pathways

If pathways are demonstrated to exist, their significance, if any, will be determined. For example, the question can be asked whether or not a particular species is dependent on an affected resource; if the answer is yes, the pathway could be considered significant. Studies to support determination of significance of identified pathways may include a review of wildlife dependence on other injured resources and the subsequent potential for exposure based on home range, feeding habits, and other factors. For example, burrowing mammals living in riparian areas may have significant exposure to hazardous substances in floodplain soils because of the nature and duration of the exposure. These reviews will rely on existing data. Information derived from other resource studies could in part provide this information (for example, riparian habitat use by dependent wildlife). If pathways were not found to be significant, injury determination for wildlife resources would not be pursued.

Concentrations of hazardous substances in pathways

If pathways are determined to exist and are found to be significant, it will be determined whether or not pathway resources contain hazardous substances at concentrations potentially sufficient to cause or have caused injury to wildlife resources. This will be accomplished through a review of published literature relevant to toxicity of specific hazardous substances to wildlife species. If it is determined that sufficient cause for injury is likely, injury determination will be pursued.

5. Tribal Injury Quantification Approach

5.1 Rationale

The Pine Nut Mountains, including the Leviathan Creek and Bryant Creek watersheds, have been a valued resource for the Washoe Tribe from time immemorial. Regular use and habitation of the Pine Nut Mountains by Washoe Tribal members, especially in the Bryant Creek drainage, has been documented through numerous interviews. Many Tribal members have spent much of the year in the Leviathan and Bryant Creek watersheds, which are recalled as areas of abundant natural resources, including watercress, willow, red ochre, deer, fish, other animals, and other resources. These areas have been identified as primary subsistence locations, where the Washoe harvest pine nuts, hunt, fish, gather, and engage in cultural ceremonies and practices. These areas support sacred and ceremonial activities as well as traditional and subsistence uses.

The Pine Nut Mountains are part of the traditional Washoe homelands, and include interconnected resources, habitats, places, remains, and cultural symbols that support and sustain the cultural integrity and continuity of the Washoe Tribe. When one or more of these elements, such as water, plants, or animals, is impacted by releases of hazardous substances, the overall ability of the area to support subsistence and traditional uses is diminished.

Prior to releases from the Leviathan Mine site, the resources of the Leviathan Creek, Bryant Creek, and East Fork Carson River watersheds provided a high level of a variety of services important to the health, welfare, economy, and cultural integrity of the Washoe Tribe. The study approach proposed in this chapter would identify those services, and determine to what extent the quality and quantity of those services have been affected as a result of the release of hazardous substances from the Leviathan Mine.

The proposed study described in this chapter is not intended to directly determine injury, but to provide a basis for quantifying injury based on an evaluation of the reduction of Tribal-specific services provided by injured resources. The results of this proposed study would be used to determine the degree to which Tribal services may have been reduced or lost because of potential injuries to surface waters, aquatic organisms, riparian resources, and other resources, if such injuries are shown through other studies.

5.2 General Study Plan

The objective of this proposed study is to identify the range of Tribal-specific uses and services that are likely to have been affected (i.e., reduced or lost) by injuries to surface water, riparian resources, and other resources in the Leviathan Creek, Bryant Creek, and East Fork Carson River watersheds.

To meet this objective, the following activities are proposed:

- Within each watershed in the assessment area, identify the resources (plants, animals, birds, fish, waters, and minerals) and their uses by the Tribe, particularly those that support the cultural integrity and continuity of the Washoe Tribe.
- Identify how these elements (resources and services) are interrelated based on traditional Washoe practices and on physical and natural processes.
- Determine to what extent injuries to one or more natural resources in the assessment area have affected the level of Tribal services provided by those resources, compared to the level of services that would have existed if not for releases from the Leviathan Mine site.

5.2.1 Inventory resources

A detailed inventory will be developed of resources, including plants, animals, birds, fish, minerals, and other natural and cultural resources, that currently exist or would most likely exist in the absence of Leviathan Mine releases in the Leviathan Creek, Bryant Creek, and East Fork Carson River watersheds. This inventory would be based on existing Tribal inventory data (based on current conditions) and on existing information from documented Tribal interviews regarding the historical extent of resources. Because some resources that existed historically in the assessment area may be absent or diminished because of reasons other than mine releases, additional field reconnaissance and inventory work will be required to determine the baseline extent of resources. Inventory methods for selecting and evaluating baseline or reference areas will be developed to identify the resources that would most likely exist in the assessment area were it not for the release of hazardous substances from the Leviathan Mine.

(Note: The specific location of certain resources may be culturally sensitive information, and therefore the existence of those resources within a watershed will be noted, but not necessarily their exact location.)

5.2.2 Identify resource services

Through interviews, literature reviews, and other appropriate sources, it will be determined how the resources identified in the inventory were or are used by (i.e., what services they provide to) the Washoe Tribe. This task will be completed, to the greatest extent possible, based on a review of existing information, including a compilation of Tribal interviews and a review of historical records that are being completed for the Washoe Tribe. This task will also involve identification of gaps in the existing data and methods of addressing those data gaps.

5.2.3 Develop Tribal-specific model

A location-specific, Tribal-specific model (i.e., dependency web, influence diagram) will be developed to illustrate the relationships between the resources identified in the inventory and the Tribal services those resources provide. The model will use baseline conditions in the assessment area. Examples of models may include work previously done by the Tribe (Washoe World Web, Washoe Tribe, undated), work currently being developed for the Tribe by Barbara Harper (Washoe Scenario), or other similar examples (Harris and Harper, 1998, 2000).

5.2.4 Develop quantification method

Based on the results of the proposed injury studies (see Chapter 4), the Tribal-specific model will be used to identify the Tribal services that have been lost or reduced as a result of documented injuries to various resources, and a method will be developed to be used in scaling projects to restore those lost or reduced services. The method for scaling restoration will be developed based on the Tribal Use Resource Equivalency Analysis model described in Chapter 6.

5.3 Pathway Considerations

Because this proposed study is intended to be part of the injury quantification phase of the assessment rather than the injury determination phase, it is based on certain assumptions about the potential outcome of other proposed injury studies. The primary transport of hazardous substances through the Leviathan Creek, Bryant Creek, and East Fork Carson River watersheds has most likely occurred through the surface water pathway. Thus, the resources most likely to be injured include surface water and other resources directly and regularly exposed to surface water, including aquatic organisms, riparian resources, and vegetation.

Additional pathways from exposed resources to Tribal resources and receptors are expected to be identified through the Tribal-specific model described in Section 5.3.3.

5.4 Quantification Approaches

Once the injury determination phase of the assessment has been completed, the effects of the release of hazardous substances will be quantified by determining the extent to which natural resource services have been reduced as a result of the injuries identified in the injury determination phase.

5.4.1 Service reduction quantification

The objective of the proposed Tribal injury quantification study is to determine the extent to which the quality and quantity of natural resource services specific to Tribal uses have been reduced as a result of the release of hazardous substances, in comparison to baseline conditions, as that term is defined in the NRDA regulations [43 CFR §11.14(e)]. Services, as defined in the regulations, include provision of habitat, food and other needs of biological resources, recreation, other products or services used by humans, flood control, groundwater recharge, waste assimilation, and other such functions that may be provided by natural resources [43 CFR §11.14(nn) and §11.71(e)].

The NRDA regulations, at 43 CFR §11.71(f), allow for direct quantification of effects on a resource by directly measuring the *change in services provided by the resource*, instead of quantifying the changes in the resource itself, if all the following conditions are met:

- The change in the services from baseline can be demonstrated to have resulted from the injury to the natural resource.
- The extent of change in the services resulting from the injury can be measured without also calculating the extent of change in the resource.
- The services to be measured are anticipated to provide a better indication of damages caused by the injury than would direct quantification of the injury itself.

The proposed study is intended to provide sufficient information to quantify injuries by directly identifying the change in the level of Tribal-specific services provided by the injured resources. With respect to Tribal-specific injuries, it is anticipated that the identification of lost or reduced services would provide a better indication of potential damages than would direct quantification of the injuries to the resources themselves. In other words, Tribal services may be lost because of resource injuries regardless of the magnitude of the injury, and therefore identifying the lost services would most accurately quantify injury.

5.4.2 Baseline services determination

Baseline services are those that are provided by a resource under conditions that would have been expected at the assessment area had the release of hazardous substances not occurred, taking into account both natural processes and those that are the result of human activities. The procedures for determining baseline services are outlined at 43 CFR §11.72.

If available and applicable, historical data for the assessment area or injured resource will be used to establish the baseline. If a significant length of time has elapsed since the discharge or release first occurred, adjustments will be made to historical data to account for changes that have occurred as a result of causes other than the discharge or release.

For this proposed study, it is expected that historical data, including literature reviews, resource inventories, and Tribal interviews, will be the primary sources of information for establishing baseline Tribal-specific services for the assessment area. Because some adjustments will be made to historical services because of other human-caused impacts to the resources in the assessment area, additional field data will be collected during the study to accurately establish baseline conditions.

6. Restoration and Compensation Determination Plan Approach for Leviathan Mine NRDA

6.1 Introduction

This chapter describes the Trustees' approach to calculating damages and planning restoration. The actual calculations and proposed restoration will be presented in the Restoration and Compensation Determination Plan (RCDP) [43 CFR §11.81-84].

6.2 Resource Categories and Lost Services

For purposes of injury quantification, the Trustees divided the natural resources into the following seven categories:

1. surface water resources
2. sediments
3. groundwater resources
4. aquatic biota
5. floodplain soils
6. riparian vegetation
7. terrestrial wildlife.

For purposes of restoration planning, the Trustees will focus on five resource services that are associated with these resource categories. Those five services may be ecological or may be associated with human uses. They are:

1. aquatic biota and supporting habitat
2. riparian vegetation
3. terrestrial wildlife
4. recreational uses
5. Tribal uses.

For each of these services, the degree and duration of diminution of services may be quantified. The Trustees propose a separate damage calculation for each service and possibly one or more restoration projects for each category. A restoration project may provide multiple benefits. Care will be taken in both the damage calculations and restoration proposals to avoid double counting of injuries and restoration benefits.

Aquatic biota and their supporting habitat

Injuries to the aquatic biota refer specifically to injuries to fish, macroinvertebrates, and other wildlife that live primarily in the waters of the streams, as well as direct injuries to the surface water resources, including sediments, of the streams. For purposes of quantification, the impacted water bodies may be divided into several sections (e.g., Aspen Creek, Leviathan Creek, Bryant Creek, and the East Fork Carson River). Such divisions would be motivated by a recognition that the degree and duration of injury vary from one stream reach to another. Such divisions will be defined after the completion of the injury assessment tasks.

Riparian vegetation

Injuries to riparian vegetation refer to injuries to those species that are directly proximate to and associated with the streams (e.g., willows). It does not refer to the sage and pines on the hillsides. As with aquatic biota, divisions associated with stream reach may be developed.

Terrestrial wildlife

Injuries to wildlife refer to those terrestrial species in the vicinity of the impacted streams. This would include birds, mammals, and other species that may inhabit upland areas and use the streams to drink or bathe, as well as for food (e.g., consumption of fish and macroinvertebrates). They may be impacted either directly (via the water or floodplain soils) or indirectly (via impacts to other species or riparian vegetation). It does not include species that reside primarily in the water (e.g., fish), since those are covered under the aquatic biota category.

Recreational uses

Recreational use refers to activities such as fishing, camping, and hiking that the general public engages in for recreational purposes. It specifically does not include uses of the resources (recreational or otherwise) by the Tribe.

Tribal resource uses

Tribal resource use refers to any uses of the natural resources in the impacted areas by members of the Tribe. These uses may include activities that have certain social, cultural, religious, medicinal, recreational, or subsistence value. Examples include camping for extended periods for pine nut gathering; drinking water; food preparation; ritual bathing; subsistence consumption of fish, wildlife, and riparian and aquatic vegetation; gathering materials and use of resources for basketmaking; and cleaning religious implements.

6.3 Methods

The economic valuation will focus on the public goods and services provided by the natural resources in the areas affected by Leviathan Mine. Private losses will not be included in this NRDA.

Most of the public goods and services potentially damaged at this site are not priced in reasonably competitive markets. However, a wide variety of well-established techniques have been developed by economists to estimate nonmarket economic values for natural resource and environmental goods and services. Any method applied here must be capable of producing a reasonably reliable, cost-effective estimate of the damages. Under federal guidelines, the Trustees have a wide range of methods that may be used [43 CFR §11.83].

The Trustees propose to use resource equivalency analysis (REA) to quantify damages for all injury categories except human recreational uses (non-Tribal). For that category, the Trustees propose employing a benefits transfer of various recreational use value studies.

The REA method is a supply-side approach, seeking to measure the cost of restoring or replacing the equivalent resources rather than the value of those resources to the public (which would be a demand-side approach). This method is relatively inexpensive and relies primarily on biological information collected to quantify natural resource injuries. It also avoids putting a direct dollar figure on the consumer surplus of the resource, relying instead on restoration-based service-to-service compensation. This is consistent with approaches recommended in the guidance regulations of CERCLA [43 CFR §11.83] and the Oil Pollution Act of 1990.

REA involves determining the amount of “natural resource services” that the affected resources would have provided had they not been injured, and it equates the quantity of lost services with those created by proposed restoration projects that would provide similar services. The unit of measure includes both the degree and the duration of injury, such as acre-years, stream feet-years, or some other metric. The size of the restoration project is scaled to the injury first. Scaling refers to the calculations required to ensure that the size of the proposed restoration project is commensurate with the size of the injury. The cost of the restoration project is then calculated after the scaling has been done. The cost of restoring a comparable amount of resources to those lost or injured is the basis for the damages. In this sense, REA calculates the *replacement cost* of the lost years of natural resource services. See Appendix A for a more detailed description of REA.

Note that the REA method inherently embeds the restoration planning process into the compensation determination process. Using a pure demand-side valuation method (such as contingent valuation), the damages may be calculated first and separately from any consideration of restoration projects. With REA, the costs of restoration projects become the basis for the damages, and thus the restoration projects inform the damage claim.

6.4 Baseline Conditions

The baseline conditions of these resources must also be determined in order to quantify the injury. The Trustees propose to evaluate baseline using nearby reference sites (e.g., Mountaineer Creek) and research on available sources of information regarding the impacted area before open pit mining in the early 1950s. Such information may include, but is not limited to, published literature, public memoranda, and interviews of individuals familiar with the area, its condition, and its recreational or Tribal uses.

6.5 Duration of Injury and Recovery Period

As of this writing (2002), the resources of the impacted area have not recovered. Response actions taken to date have not restored the natural resources injured by releases of hazardous substances. Expansion of remedial efforts under EPA's authority may result in substantial improvement to natural resources, but completion of EPA's RI/FS process and implementation of a final remedy are years away. Interim losses will continue to accrue until the remedy is completed, and residual injury after completion of EPA's remedial measures is a possibility. Thus, the Trustees may either estimate a time until full recovery based on various hypotheses or wait until the recovery is complete. Because of the uncertainty and long timelines associated with remediation, the Trustees have chosen the former course; they will estimate when recovery will occur.

Specifically, the Trustees will evaluate several scenarios for each injury category. These scenarios will assume different levels of success of the remediation of the mine site. Under each scenario, different impacted resources (e.g., fish and macroinvertebrates) may recover at different rates. One scenario may be that the impacted resources will not recover without active restoration even after remediation is completed. In this case, the Trustees will incorporate the need for primary restoration to ensure full recovery of the impacted areas.

The Trustees will evaluate the success of remediation efforts throughout the NRDA process. This evaluation will enable the Trustees to discern which scenario is most applicable to the damage calculations. The Trustees will also revise scenarios as more information becomes available.

6.6 Degree of Injury

The degree of injury will be based on all available data that will help the Trustees determine the change in the resources relative to baseline conditions.

Aquatic biota, riparian vegetation, and terrestrial wildlife

All available data regarding the spatial and temporal extent of the injury will be used to estimate the degree of injury over time. Specifically, the Trustees will examine data related to toxicity, community composition, species population and density, and any other relevant information.

Recreational uses (fishing)

Non-Tribal recreational use injuries and damages are currently being examined. The Trustees will focus on recreational fishing along Leviathan and Bryant creeks and East Fork Carson River, comparing current usage to an estimate of baseline use. The degree of injury will be quantified in terms of lost angler-days. Unlike REA, the calculation of damages is not based on the cost to restore or re-create a like number of angler-days. Rather, the Trustees are taking advantage of numerous studies that estimate the value of a recreational fishing day and will apply an appropriate value to this case. This method is termed benefits transfer. Because of its reliance on previous studies in the literature, its application may be very cost-effective.

While the Trustees believe that impacts on other recreational activities (e.g., camping, hiking) may have occurred, they have decided that the costs of quantifying these losses would most likely exceed the damages. Thus, the Trustees are not seeking to quantify impacts to recreational activities other than fishing.

Tribal resource uses

Impacts to Tribal use of natural resources represent an additional human use injury. The Tribe has effectively been prevented from accessing many of the natural resources in the impacted area for a variety of uses. These uses often have social, cultural, religious, medicinal, recreational, and subsistence values. While these uses may generate even more value to the Tribal users than recreational fishing, these uses have not been the source of numerous economic studies. Thus, the benefits transfer method would be difficult to use in determining the value of these Tribal uses.

Instead, the Trustees propose to employ a Tribal Use REA, comparing the benefits of a restoration project to the impacts of the injury. The degree of injury will be the degree to which the Tribe has been precluded from using a particular resource (e.g., fish, plants). Specifically, the Tribal Use REA will use land access as its metric. Given that the Tribe has been prevented from using the natural resources in the impacted area (to one degree or another), this injury will be scaled to a restoration project (such as the acquisition of land) that will provide similar services. Note that the metric here is Tribal access to resources and not the various activities that utilize these resources.

In seeking to acquire the equivalent in Tribal access to resources, the relative value of the project area to the impacted area will be evaluated based on the abundance of resources, distance from the Tribe, and other relevant attributes. Unique religious and cultural values associated with the impacted area will be considered as well. As with any equivalency analysis, the duration of the benefits will be calculated to offset the duration of the injury. Thus, the Tribal Use REA will involve a comparison of the size and attributes between the impacted area and the project site, as well as a scaling exercise based on the degree and duration of the injury and the benefits. The advantage of this restoration-based approach is that it avoids placing a dollar value directly on activities that have cultural and religious significance. The Trustees will make all efforts to avoid double counting when evaluating the benefits of the project.

6.7 Summary of Damage Quantification

Table 6.1 summarizes the proposed bases and methods that will guide the Trustees in the course of quantifying injuries and damages.

Table 6.1. Damage quantification approaches by resource services.

	Aquatic biota and habitat	Riparian vegetation	Terrestrial wildlife	Recreational uses	Tribal uses
Baseline evaluation	Reference sites and research into the area before 1950 will be used.				
Degree of injury	All available data on water, sediment, and biota	All available data on water, soil, and plants	All available data on water and animals	Estimated lost angler use	Lost availability for Tribal uses
Duration of injury	Multiple scenarios of recovery trajectories will be examined.				
Valuation method	Instream REA	Riparian REA	Wildlife REA	Benefits transfer	Tribal use REA

6.8 Restoration Planning Process

The overall goal of the Trustees is to develop a comprehensive plan to restore natural resources and the services they provide to baseline conditions. The final step of the NRDA process is the development of Draft and Final Restoration Plans that identify specific alternatives for restoration. Restoration can include restoring, rehabilitating, replacing, or acquiring the equivalent of the injured natural resources and the services they previously provided [43 CFR §11.81(a)(I)]. The Trustees intend to prepare a Restoration Plan after damages are recovered. A Restoration Plan may include any combination of these management approaches. This plan will propose certain projects and be open to public comment and suggestions regarding changes to those projects, the demerits of those projects, or the inclusion of new projects. After the public comment period, the Final Restoration Plan will be issued. The Trustees will then begin implementing the plan.

Because restoration project benefit and cost information is used in the damage calculations in REA, it is necessary to identify potential projects when estimating damages. These restoration benefit and cost data may be based on projects to be implemented once damages are recovered, on previous projects already implemented, or on an aggregate of projects (e.g., using average restoration costs). The projects used for estimating damages are therefore not necessarily the same projects that will be selected in the Final Restoration Plan. However, an effort will be made to ensure that the projects used in the damage calculations provide the same services and have similar costs as the projects to be implemented. Thus, the project selection criteria proposed below are relevant to both projects to be used for damage calculations and projects to be implemented as actual restoration.

In selecting projects for implementation, the Trustees may consider both on-site and off-site restoration. Off-site restoration seeks to restore some other degraded habitat (presumably nearby and of similar type) to compensate the public for the interim losses at the impacted site.

6.9 Project Selection Criteria

The Trustees proposed to examine all projects to compensate for public use losses and projects to restore natural resources using the criteria described here. Proposed projects must achieve a minimum level of acceptance under all the “threshold” criteria to receive further consideration under the “additional” criteria.

Threshold criteria

Technical feasibility: A proposed restoration project must be technically sound. The Trustees will consider the level of uncertainty or risk involved in implementing the project. A proven track record that shows past successes of similar projects will be beneficial.

Consistency with the Trustees’ restoration goals: Proposed projects must meet the Trustees’ intent to compensate the public for lost natural resource services that were affected.

Compliance with laws and public safety: A proposed restoration project must comply with all applicable laws and should not create a risk to public health or safety.

Additional criteria

Connection ("nexus") to impacts caused by incident: Under this criterion, projects that benefit the same type of resource or services that were lost (e.g., instream habitat, access for Tribal uses) are preferred over projects that benefit other activities or resources.

Likelihood of success: The Trustees will consider factors affecting the likely success of a project. Projects that have less risk or uncertainty (e.g., technical, political) regarding the potential to succeed are preferred under this criterion. The Trustees will also consider the ability to monitor and evaluate project success, the ability to correct problems that arise during implementation, and the qualifications of companies or individuals expected to implement a project.

Absence of negative side effects: All projects will be evaluated for potential negative side effects on other natural resources. This is especially important for human use projects. Such negative effects should be avoided.

Opportunities for partners or collaboration: The Trustees will consider the possibility of receiving matching funds or other forms of support to increase the expected benefits of a proposed project. The Trustees will also evaluate potential coordination with other ongoing or proposed projects.

Lack of alternative funding sources: The Trustees will consider only projects that otherwise would not be funded in the foreseeable future. The Trustees will not fund projects that are scheduled to be implemented with funds from another source.

Benefits and costs: Under this criterion, the Trustees will evaluate the expected project benefits and the expected project costs. Proposed projects that are the least costly (i.e., most cost-efficient) way to provide a particular type and amount of benefit will be favored.

Note that the degree and duration of benefits of the project are built into the REA process and are therefore inherently considered in the scaling of the size of the project.

6.10 Restoration Categories

The types of projects proposed for restoration will fall into the same service categories as the injury. That is, a project or suite of projects will be proposed to restore aquatic biota and their habitat, and the same for riparian vegetation, terrestrial wildlife, recreational uses, and Tribal uses.

At present, the Trustees are considering the following types of restoration projects:

Aquatic biota and their supporting habitat

Off-site projects to benefit aquatic biota may include any measures to restore degraded mountain streams on the east side of the Sierra. Projects may include any efforts to improve fish and/or macroinvertebrate populations. On-site projects to restore the impacted streams to baseline may include restoration of Lahontan cutthroat trout.

Riparian vegetation

Any project that seeks to restore degraded riparian vegetation along east side Sierra streams will be considered. Should these projects be deemed to have corollary benefits to aquatic biota, credit for those benefits will be considered to avoid double counting.

Terrestrial wildlife

Any project that seeks to restore the same species of terrestrial wildlife deemed impacted will be considered. Preference will be given to projects close to the impacted area.

Recreational uses (fishing)

Any project that seeks to increase or augment the value of recreational use near the impacted streams will be considered. Such projects may include fish planting or the provision of services to improve fishing access or the quality of the experience. Both on-site and off-site projects will be considered.

Tribal resource uses

As described earlier, any project that provides the Tribe with access to resources that provide similar opportunities for the uses lost because of the releases of hazardous substances will be considered. If the Tribe should ultimately choose a project that involves land acquisition, the services provided by the land considered for acquisition will be compared to those services lost in the impacted area. The Trustees will evaluate the relative values of these lands to determine an appropriate scaling metric. If the land considered for acquisition is of lesser value, the project may include restoration, or additional land may be purchased to compensate for the difference in value. Note that such a project will not simultaneously provide compensation for the other restoration categories described above. Again, the Trustees will make all efforts to avoid double counting when evaluating the benefits of the projects.

6.11 Restoration Costs

Except for recreational fishing losses, where the damages will be calculated using the benefits transfer method, all damages will be based on restoration costs. That is, the costs of proposed or similar projects, scaled to the size of the injury, will provide the basis for the damage claim.

The costs of a restoration project will include all planning, permitting, implementation, and (if applicable) agency oversight, monitoring, and compliance costs. A minimum of five-year monitoring for the restoration of wildlife and habitat will be required. The monitoring period may be longer if the Trustees believe that is warranted. Additionally, the overall damage claim will include a budget for the Trustee Council, who will incur costs in the development of a Restoration Plan and throughout the project selection and implementation period.

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A. Resource Equivalency Analysis

A.1 Background

There are two basic approaches to measuring the value of natural resources. One is to focus on the demand side, the "consumer valuation approach;" the other is to focus on the supply side, the "replacement cost" approach. In the former, we seek to measure the monetary value that the public puts on the natural resources (i.e., how much the public demands the services of natural resources); in the latter, we seek to measure how much it costs to replace the natural resources if they are injured (i.e., how much it costs to supply natural resource services). See the glossary at the end of this appendix for complete definitions of some of the terms used here.

Figures A.1 and A.2 illustrate the difference between these two approaches. In both figures, the supply of natural resources shifts from S1 to S2 in the event of an oil spill. Figure A.1 illustrates the loss of consumer surplus resulting from this decrease in natural resources. However, because there are no observable market prices, the demand curve and our relative location on the vertical axis (how much the public values the resource) are difficult to measure. Contingent valuation (CV) and other types of analyses are designed to measure the lost consumer surplus. These methodologies typically involve large surveys and can be costly.

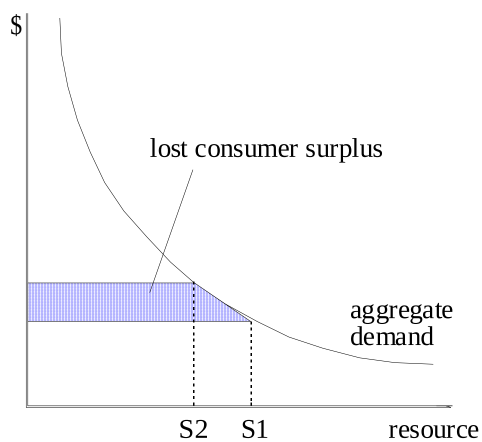

Figure A.1. Consumer valuation approach.

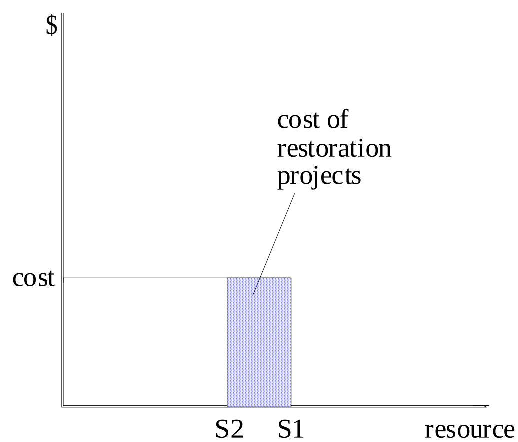

Figure A.2. Replacement cost approach.

Figure A.2 illustrates a simple replacement cost approach. In this case, the demand of the public for the resource and how much the public values the resource are not considered. Instead, the resource is valued according to the cost of replacing it. Resource equivalency analysis (REA) is the primary method for this type of measurement. Note that the cost of restoring habitat (labeled "cost" on the vertical axis) is not necessarily correlated with the public's valuation of the resource, nor is the lost consumer surplus (the shaded area in Figure A.1) necessarily equal to the total replacement cost (the shaded area in Figure A.2). This is especially true when unique resources or rare species are involved, as the public demand for them may be much more inelastic (i.e., a more vertical demand curve; the public demand is more fixed and less a function of price), resulting in a much larger loss of consumer surplus. In such a case, the replacement cost approach of REA may result in damages far less than the losses as valued by the public. However, because it is easier and less costly to measure the total replacement cost than the lost consumer surplus, REA has an advantage over other methods, especially for small to medium-sized spills with minimal impact on rare species.

A.2 Resource Equivalency Analysis

REA is relatively inexpensive and relies primarily on biological information collected while determining natural resource injuries caused by the spill. It also avoids putting a direct dollar figure on the consumer surplus of the resource, relying instead on restoration-based service-to-service compensation. This is consistent with approaches recommended in the language of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) and the Oil Pollution Act of 1990.

REA involves determining the amount of "natural resource services" that the affected resources would have provided had it not been injured, and it equates the quantity of lost services with those created by proposed compensatory restoration projects that would provide similar services. The unit of measure may be acre years, stream feet years, or some other metric. The size of the restoration project is scaled to the injury first; the cost of restoration is then calculated after the scaling has been done. The cost of restoring a comparable amount of resources to those lost or injured is the basis for the compensatory damages. In this sense, REA calculates the *replacement cost* of the lost years of natural resource services.

Future years are discounted at 3% per year, consistent with NOAA recommendations for natural resource damage assessments. Discounting of future years is done based on the assumption that present services are more valuable than future services. When it comes to natural resources, the question of whether or not society should value the present more than future is a philosophical question (e.g., one can recall the "greenhouse effect" and the question of how much expense we should incur today to preserve the future). However, the question of how much society actually discounts the value of future natural resources is an empirical one. The 3% figure is currently the standard accepted discount rate for natural resource damage assessments.

REA involves three steps: 1) the debit calculation, 2) the credit calculation, and 3) the computation of the costs of restoration. These calculations can be done in a variety of ways, but the most common is to estimate the injury and the restoration benefits in terms of area years of habitat or animal years.

A.3 Habitat Example

For example, suppose a 10 acre area is degraded by a spill, and supplies only 30% of its previous habitat services during the year following the incident. In the second year after the incident, the habitat begins to recover, supplying 90% of its baseline services. By the third year it is fully recovered. In this case, the lost acre years of habitat services would be 70% x 10 acres x 1 year + 10% x 10 acres x 1 year = 8 acre years of habitat services. Figure A.3 illustrates this example by showing the recovery path of the habitat over time.

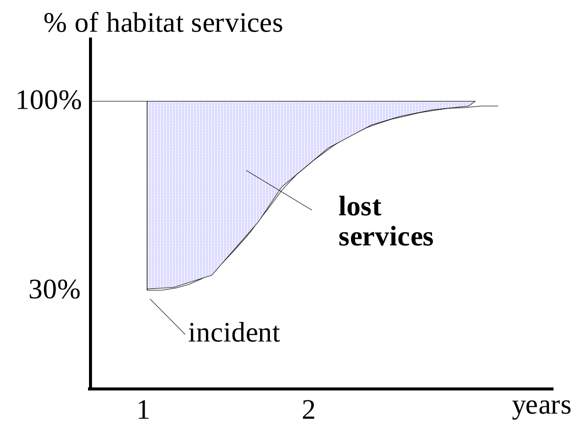

Figure A.3. Recovery path of habitat.

As stated above, future years are discounted at a 3% rate, thus the injuries in the second year count a little less. Incorporating this, 7.97 acre years of habitat services were lost. This difference appears minimal here, but becomes significant (because of compounding) if injuries persist many years into the future.

The credit calculation focuses on the gain in habitat services that result from a restoration project. Creating acre years of habitat services is a function of both area and time. Hypothetically, compensation could involve taking 7.97 acres of land with no habitat value (e.g., a parking lot) and turning it into productive habitat for 1 year. Alternatively, we could achieve compensation by creating 1 acre for 7.97 years. In reality, most restoration projects involve taking previously degraded habitat (at another nearby location) and restoring it over a number of years, and maintaining it into the future.

Suppose the restoration project improves the quality of a nearby degraded area, so that, if it previously provided only 30% of potential services, it would provide 80% of potential habitat services after restoration. Also suppose the project begins 2 years after the incident and the benefits are realized over the period of a few years, so that it takes 5 years for the 80% level to be achieved. Once achieved, the project is expected to have a lifespan of 20 years. Figure A.4 provides an illustration of the restoration trajectory. Note that, with future years discounted, the 20th year counts little; years after that are effectively completely discounted because of uncertainty regarding the future.

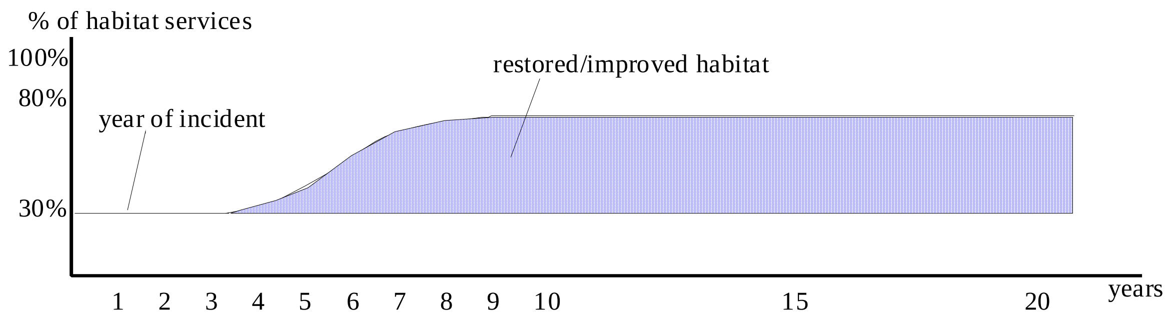

Figure A.4. Restoration trajectory for credit calculation.

Mathematically, we seek to restore an area that will provide 7.97 acre years of services over the discounted 20-year phased-in life span of the restoration project. In this example, that would be an area of about 1.3 acres. That is to say, restoration of 1.3 acres for 20 years would compensate the public for the 7.96 lost acre years of habitat services due to the spill. Visually, the shaded area in Figure A.3 (multiplied by the affected acres and calculated to measure the present discounted value) should equal the shaded area in Figure A.4 (again, multiplied by the acres targeted for restoration and calculated to measure the present discounted value, thus discounting future years).

The percentage of habitat services lost (or gained, in the case of the restoration project) can be measured in a variety of ways. Three examples are the use of a habitat-wide evaluation index, the use of one or more surrogate species, or the use of an estimate based on the degree of oiling. Care must be taken when using a surrogate species to represent the entire affected habitat. Ideally, this surrogate is the population of one or more species that is immobile (that is, the animals do not move easily in and out of the affected area) and that has significant forward and/or backward ecological links to other species in the affected ecosystem. For example, the population of red crossbills, a bird that feeds primarily on pine cone seeds and migrates erratically from year to year, would be a poor surrogate for measuring injuries to a streambed. The aquatic macroinvertebrate community within the stream, however, provides an ideal surrogate, as they play a key role in the streambed food chain. Likewise, on the restoration side, care must taken when the project targets one or a few species rather than the entire habitat. Ideally, a project that seeks to restore the population of a key indicator species will also benefit the entire habitat and, thus, other species as well. Indeed, such projects typically focus directly on habitat improvements. However, it is important to verify that such a species-centered project is indeed benefiting the entire habitat.

A.4 Animal Example

When the injury is primarily to individual animals rather than a complete habitat, the REA may focus on lost animal years. For example, suppose an oil spill causes negligible injury to a body of water, but results in the death of 100 ducks. Information about the life history of the ducks (e.g., annual survival rate, average life expectancy, average fledging rate) allows estimation of the “lost duck years” due to the spill. On the credit side, restoration projects can be designed to create duck nesting habitat and the size of the project can be scaled to create as many duck years as were lost in the incident.

A.5 Restoration Costs — Natural Resource Damages

Once the proposed restoration projects are scaled to provide services equal to the those lost because of the incident, the cost of the projects can be calculated. Note that this is the first time dollar figures enter the REA process. Until now, all the calculations of the “equivalency” have been in terms of years of resource services. The cost of the restoration projects is the compensatory damage of the incident.

For another explanation of the REA method (in its more specific form for habitats), see “Habitat Equivalency Analysis: An Overview,” prepared by NOAA. Copies of this document are available at http://www.darp.noaa.gov/publicat.htm

Glossary

Aggregate demand

The demand of all consumers combined; e.g., if there are 20,000 people in a town and each person demands two pieces of bread each day, the aggregate demand is 40,000 pieces of bread per day.

Consumer surplus

The difference between the total value consumers receive from the consumption of a particular good and the total amount they pay for the good; e.g., a person may value that first Coke (on a hot day) at $2.00, but is only willing to pay $1.00 for a second one, and a third one would only be worth 25 cents to them. If a Coke costs 70 cents, they would buy two. They would spend $1.40 on the two Cokes, but receive $3.00 in value. Thus, their consumer surplus (like “profit” for the consumer) would be $1.60.

Compensatory restoration

A restoration project which seeks to compensate the public for temporal or permanent injuries to natural resources; e.g., if a marsh is injured by an oil spill and recovers slowly over ten years, a compensatory project (which may be off site) seeks to compensate the public for the 10 years of diminished natural resources.

Discount rate

The rate at which the future is discounted, i.e., the rate at which the future does not count as much as the present; e.g., a dollar a year from now is worth less than a dollar today; if the bank offers a 3% rate, whereby $1.00 becomes $1.03 in 1 year, the future was discounted at 3%.

Primary restoration

A restoration project that seeks to help an injured area recover more quickly from an injury; e.g., if a marsh is injured by an oil spill and would recover slowly over 10 years if left alone, a primary restoration project might seek to speed the recovery time of the marsh and achieve full recovery after 5 years.

Replacement cost

The cost of replacing that which was lost; e.g., if 50 acre-years of habitat services were lost because of an oil spill, the cost of creating 50 acre-years of similar habitat services would be the replacement cost.

B. Quality Assurance Project Plan

B.1 Introduction

This Quality Assurance Project Plan (QAPP) has been developed to support studies that may be performed as part of the Leviathan NRDA. Under the NRDA regulations [43 CFR§ 11.31], the QAPP is required to develop procedures to ensure data quality and reliability. This QAPP is intended to provide quality assurance/quality control (QA/QC) procedures, guidance, and targets for use in future studies conducted for the NRDA. It is not intended to provide a rigid set of predetermined steps with which all studies must conform or against which data quality is measured, nor is it intended that existing data available for use in the NRDA must adhere to each of the elements presented in this QAPP. Ultimately, the quality and usability of data are based on methods employed in conducting studies, the expertise of study investigators, and the intended uses of the data. The QAPP has been designed to be consistent with the NCP and EPA's Guidelines and Specifications for Preparing Quality Assurance Project Plans (EPA, 1998b).

The elements outlined in this plan are designed to:

- provide procedures and criteria for maintaining and documenting custody and traceability of environmental samples
- provide procedures and outline QA/QC practices for the sampling, collection, and transporting of samples
- outline data quality objectives (DQOs) and data quality indicators
- provide a consistent and documented set of QA/QC procedures for the preparation and analysis of samples
- help to ensure that data are sufficiently complete, comparable, representative, unbiased, and precise so as to be suitable for their intended uses.

Before the implementation of NRDA studies, Standard Operating Procedures (SOPs) providing descriptions of procedures typically will be developed. These SOPs will be appended to this QAPP, as developed, to provide an ongoing record of methods and procedures employed in the assessment. SOPs will be developed and updated as methods and procedures are reviewed and accepted for use.

B.2 Project Organization and Responsibility

Definition of project organization, roles, and responsibilities helps ensure that individuals are aware of specific areas of responsibility that contribute to data quality. However, fixed organizational roles and responsibilities are not necessary and may vary by study or task. An example of project quality assurance organization, including positions with responsibility for supervising or implementing quality assurance activities, is shown in Figure B.1. Key positions and lines of communication and coordination are indicated. Descriptions of specific quality assurance responsibilities of key project staff are included below. Only the project positions related directly to QA/QC are described; other positions may be described in associated project plans. Specific individuals and laboratories selected to work on this investigation will be summarized and appended to this QAPP or included in study-specific SOPs when they are established.

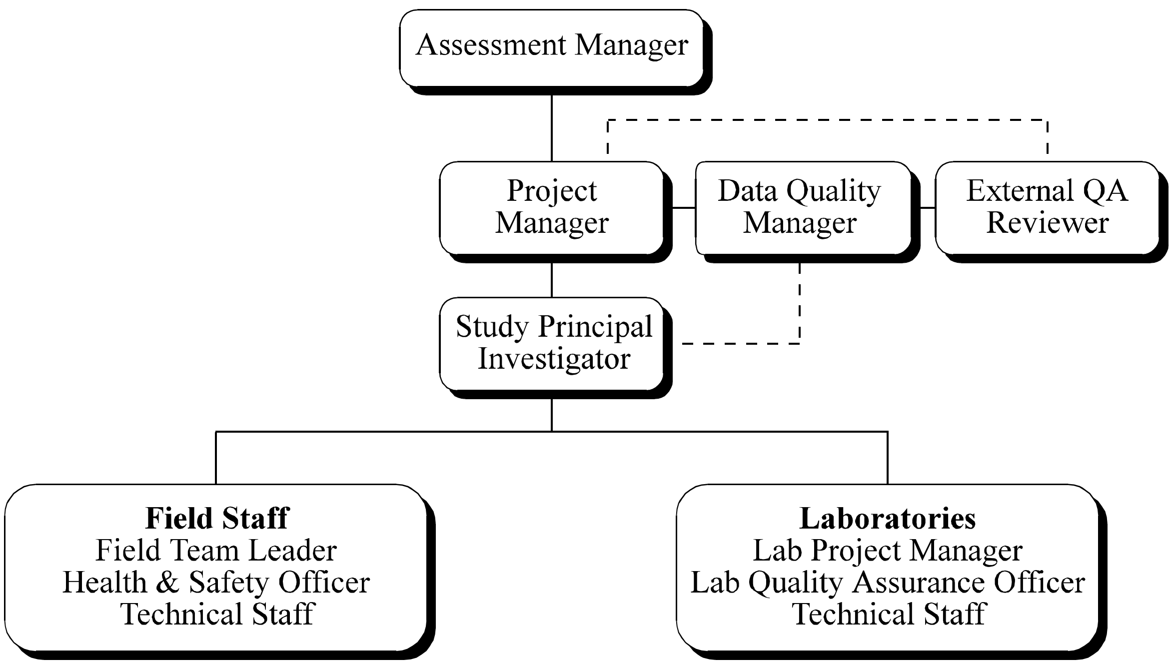

Figure B.1. Project organization.

B.2.1 Assessment Manager and Project Manager

The Assessment Manager (AM) is responsible for all technical, financial, and administrative aspects of the project. The Project Manager (PM) supports the AM and is responsible for producing quality data and work products for this project within allotted schedules and budgets. Duties include executing all phases of the project and efficiently applying the full resources of the project team in accordance with the project plans. Specific QA-related duties of the AM and the PM can include:

- coordinating the development of a project scope, project plans, and data quality objectives
- ensuring that written instructions in the form of SOPs and/or associated project plans are available for activities that affect data quality
- monitoring investigative tasks for their compliance with plans, written procedures, and QC criteria
- monitoring the performance of subcontractors in regard to technical performance and specifications, administrative requirements, and budgetary controls
- participating in performance and/or systems audits and monitoring the implementation of corrective actions
- reviewing, evaluating, and interpreting data collected as part of this investigation
- supervising the preparation of project documents, deliverables, and reports
- verifying that all key conclusions, recommendations, and project documents are subjected to independent technical review, as scheduled in the project plans.

B.2.2 Data Quality Manager

A Data Quality Manager can be assigned to be responsible for overall implementation of the QAPP. Duties include conducting activities to ensure compliance with the QAPP, reviewing final QA reports, preparing and submitting QA project reports to the AM and PM, providing technical QA assistance, conducting and approving corrective actions, training field staff in QA procedures, and conducting audits, as necessary. Specific tasks may include:

- assisting the project team with the development of data quality objectives
- managing the preparation of and reviewing data validation reports
- submitting QA reports and corrective actions to the PM
- ensuring that data quality, data validation, and QA information are complete and are reported in the required deliverable format
- communicating and documenting corrective actions
- maintaining a copy of the QAPP
- supervising laboratory audits and surveillance
- ensuring that written instructions in the SOPs and associated project plans are available for activities that affect data quality
- monitoring investigative tasks for their compliance with plans, written procedures, and QC criteria
- monitoring the performance of subcontractors in regard to technical performance and specifications, administrative requirements, and budgetary controls
- reviewing, evaluating, and interpreting data collected as part of this investigation.

B.2.3 External QA Reviewer

External QA Reviewers can review QA documentation and procedures, perform data validation, and perform field and laboratory audits if needed.

B.2.4 Principal Investigator

Study-specific Principal Investigators (PIs) ensure that QA guidance and requirements are followed. The PI or the designee will note significant deviations from the QAPP for the study. Significant deviations will be recorded and promptly reported to the PM and Data Quality Manager. In addition, the PI typically is responsible for reviewing and interpreting study data and preparing reports.

B.2.5 Field Team Leader

The Field Team Leader (FTL) supervises day-to-day field investigations, including sample collection, field observations, and field measurements. The FTL generally is responsible for all field QA procedures defined in the QAPP, and in associated project plans and SOPs. Specific responsibilities may include:

- implementing the field investigation in accordance with project plans
- supervising field staff and subcontractors to monitor that appropriate sampling, testing, measurement, and recordkeeping procedures are followed
- ensuring the proper use of SOPs associated with data collection and equipment operation
- monitoring the collection, transport, handling, and custody of all field samples, including field QA/QC samples
- coordinating the transfer of field data, including field sampling records, chain-of-custody records, and field logbooks
- informing the PI and Data Quality Manager when problems occur, and communicating and documenting any corrective actions that are taken.

B.2.6 Laboratory Project Manager

A Laboratory Project Manager can be responsible for monitoring and documenting the quality of laboratory work. Duties may include:

- ensuring that the staff and resources produce quality results in a timely manner are committed to the project
- ensuring that the staff are adequately trained in the procedures that they are using so that they are capable of producing high quality results and detecting situations that are not within the QA limits of the project
- ensuring that the stated analytical methods and laboratory procedures are followed, and the laboratory's compliance is documented
- maintaining a laboratory QA manual and documenting that its procedures are followed
- ensuring that laboratory reports are complete and reported in the required deliverable format

- communicating, managing, and documenting all corrective actions initiated at the laboratory

- notifying the Data Quality Manager, within one working day of discovery at the laboratory, of any situations that will potentially result in qualification of analytical data.

B.2.7 Technical staff

Project technical staff represent a variety of technical disciplines and expertise. Technical staff should have adequate education, training, and specific experience to perform individual tasks, as assigned. They are required to read and understand any documents describing the technical procedures and plans that they are responsible for implementing.

B.3 Quality Assurance Objectives for Measurement Data

B.3.1 Overview

The overall QA objectives are to help ensure that the data collected are of known and acceptable quality for their intended uses. QA objectives are qualitative and quantitative statements that aid in specifying the overall quality of data required to support various data uses. These objectives often are expressed in terms of accuracy, precision, completeness, comparability, representativeness, and sensitivity. Laboratories involved with the analysis of samples collected in support of this NRDA will make use of various QC samples such as standard reference materials (SRMs), matrix spikes, and replicates to assess adherence to the QA objectives discussed in the following sections and in specific laboratory QA/QC plans. Field and laboratory QC targets for chemical analyses, frequency, applicable matrices, and acceptance criteria are listed in Table B.1.

Because numeric QC criteria are specific to a study, method, or laboratory, criteria are not included in this QAPP. When appropriate, criteria can be established when study and method procedures are approved; such criteria will be appended to this QAPP or included in study-specific SOPs. Criteria will be determined based on factors that may include:

- specific analytical methods and accepted industry standards of practice
- matrix-specific control limits for acceptable sample recovery, accuracy, or precision
- historical laboratory performance of selected analytical methods
- intended uses of the data.

Table B.1. Laboratory and field quality control sample targets for chemical analyses.

QC element	Target frequency	Applicable matrices	Target acceptance criteria
Method blank	1 in 20 samples	S, SW, T	Method dependent
Laboratory duplicate	1 in 20 samples	S, SW, T	Method dependent
Matrix spike	1 in 20 samples	S, SW, T	Method dependent
Standard reference material	1 in 20 samples	S, SW, T	Method dependent
Equipment blank	1 in 20 samples	SW	Study dependent
Field duplicate	1 in 20 samples	S, SW, T	Study dependent
Surrogates	All samples for organics analysis	S, SW, T	Method dependent
Laboratory control sample	1 in 20 samples	S, SW, T	Method dependent

S = sediment; SW = surface water; T = tissue.

Where statistically generated or accepted industry standards of practice are not available, QC criteria may be defined by the Data Quality Manager working with the Laboratory QA Officer and PIs.

B.3.2 Quality control metrics

Accuracy

Accuracy is a quantitative measure of how close a measured value lies to the actual or “known” value. Sampling accuracy is partially evaluated by analyzing field QC samples such as field blanks, trip blanks, and rinsates (or equipment blanks). In these cases, the “true” concentration is assumed to be not detectable, and any detected analytes may indicate a positive bias in associated environmental sample data.

Laboratory accuracy is assessed using sample (matrix) spikes and other QC samples. For example, a sample (or blank) may be spiked with an inorganic compound of known concentration and the average percent recovery (%R) calculated as a measurement of accuracy. A second procedure is to analyze a standard (e.g., SRMs or other certified reference materials) and calculate the %R for that known standard. As an additional, independent check on laboratory accuracy, blind SRMs submitted as field samples may be used.

Accuracy criteria are established statistically from historical performance data, and often are based on confidence intervals set about the mean. Where historical data are not adequate for statistical calculations, criteria may be set by the Laboratory Project Manager, Data Quality Manager, and PIs. Accuracy criteria will be appended to this QAPP or included in study-specific SOPs, when established. Accuracy may be assessed during the data validation or data quality assessment stage of these investigations.

Precision

Precision is a measure of the reproducibility of analytical results under a given set of conditions. The overall precision of a set of measurements is determined by both sampling and laboratory variables. Reproducibility is affected by sample collection procedures, matrix variations, the extraction procedure, and the analytical method.

Field precision typically is evaluated using sample replicates, which are usually duplicate or triplicate samples. Sample replicates may be generated by homogenizing the sample, splitting the sample into several containers, and initiating a blind submittal to the laboratory with unique sample numbers. For a duplicate sample, precision of the measurement process (sampling and analysis) is expressed as:

$$\text{Relative Percent Difference (RPD)} = \frac{(\text{Duplicate Sample Result - Sample Result})}{(\text{Duplicate Sample Result + Sample Result})} \text{ x } 200.$$

For a triplicate analysis, precision of the sampling and analysis process is expressed as:

$$\text{Percent Relative Standard Deviation (\% RSD)} = \frac{\sigma_{n-1}}{\text{Mean}} \text{ x } 100,$$

where σ_{n-1} is the standard deviation of the three measurements.

Laboratory precision typically is evaluated using laboratory duplicates, matrix spike duplicates, or laboratory control sample or SRM duplicate sample analysis. Duplicates prepared in the laboratory are generated before sample digestion. Laboratory precision is also expressed as the relative percent difference (RPD) between a sample and its duplicate, or as the %RSD for three values.

Precision criteria are established statistically from historical performance data, and are usually based on the upper confidence interval set at two standard deviations above the mean. Where historical data are not adequate for statistical calculations, criteria may be set by the Laboratory

Project Manager, Data Quality Manager, and PIs. Precision criteria will be appended to this QAPP or included in study-specific SOPs, when established.

Completeness

Completeness is defined as the percentage of measurement data that remain valid after discarding any invalid data during the field or laboratory QC review process. A completeness check may be performed following a data validation process. Analytical completeness goals may vary depending on study type, methods, and intended uses of the data.

Analytical data completeness will be calculated by analyte. The percent of valid data is 100 times the number of sample results not qualified as unusable (R), divided by the total number of samples analyzed. Data qualified as estimated (J) because of minor QC deviations (e.g., laboratory duplicate RPD exceeded) will be considered valid.

Comparability

Comparability is a qualitative parameter expressing the confidence with which one dataset can be compared to another. Comparability is facilitated by use of consistent sampling procedures, standardized analytical methods, and consistent reporting limits and units. Data comparability is evaluated using professional judgment.

Representativeness

Representativeness expresses the degree to which data accurately and precisely represent a defined or particular characteristic of a population, parameter variations at a sampling point, a processed condition, or an environmental condition. Representativeness is a qualitative parameter that is dependent on the proper design of the sampling program and proper laboratory protocol. Sampling designs for this investigation will be intended to provide data representative of sampled conditions. During development of sampling plans and SOPs, consideration will be given to existing analytical data, environmental setting, and potential industrial sources. Representativeness will be satisfied by ensuring that the sampling plan is followed.

Sensitivity

Detection limit targets for each analyte and matrix will be appended to this QAPP or included in study-specific SOPs as they are established.

B.4 Sampling Procedures

B.4.1 Sample collection

Samples are collected and handled in accordance with the procedures contained in SOPs or associated project plans. These documents typically describe sample collection, handling, and documentation procedures to be used during field activities. SOPs and work plans/protocols may cover the following topics, as appropriate:

- procedures for selecting sample locations and frequency of collection
- sample site selection, positioning, and navigation procedures
- sampling equipment operation, decontamination, and maintenance
- sample collection and processing, which includes sample collection order and homogenization procedures, sample containers, and volume required
- field QC sample and frequency criteria
- sample documentation, including chain-of-custody (COC) and field documentation forms and procedures
- sample packaging, tracking, storage, and shipment procedures.

B.4.2 Sample containers, preservation, and holding times

Containers will be prepared using EPA specified or other professionally accepted cleaning procedures. Analysis statements for containers prepared by third-party vendors will be included in the project file. Since the investigations involved with this NRDA may involve samples not amenable to typical environmental sample containers (such as whole body tissue samples), multiple types of containers may be required. Sample containers may include aluminum foil and watertight plastic bags for tissue samples and whole body samples.

When appropriate, sample coolers will contain refrigerant in sufficient quantity to maintain samples at the required temperatures until receipt at the laboratories.

B.4.3 Sample identification and labeling procedures

Before transportation, samples should be properly identified with labels, tags, or markings. Identification and labeling typically includes, but need not be limited to, the following information:

- project identification
- place of collection
- sample identification
- analysis request
- preservative
- date and time of collection
- name of sampler (initials)
- number of containers associated with the sample.

B.4.4 Field sampling forms

Field sampling forms should be described in the appropriate SOP or associated project plans. Forms typically must be completed in the field at the same time as the sample label. As with the sample label, much of the information can be preprinted, but date, time, sampler's initials, and other specific field observations should be completed at the time of sampling.

B.4.5 Sample storage and tracking

In the field, samples may be stored temporarily in coolers with wet or dry ice (as appropriate). Security should be maintained and documentation of proper storage should be provided in the project field notebook. Samples stored temporarily in coolers should be transported to a storage facility as soon as logistically possible. When possible, samples will be shipped directly to the appropriate laboratories from the field.

Before analysis, samples will be stored under appropriate conditions at the storage facility or laboratory (refrigerator or freezer). Security should be maintained at all times. A log book or inventory record typically is maintained for each sample storage facility refrigerator or freezer. The log books or inventory records are used to document sample movement in and out of the facility. In general, samples will be placed into a freezer and information regarding sample identification, matrix, and study will be recorded. Additional information in the record for each sample may include the date of the initial storage, subsequent removal/return events with associated dates, and initials of the person(s) handling the samples. Additional information may also include study name and special comments. If required, unused samples or extra samples will be archived in a secure location under appropriate holding conditions to ensure that sample integrity is maintained.

Documentation should allow for unambiguous tracking of the samples from the time of collection until shipment to the laboratory. The tracking system should include a record of all sample movement and provide identification and verification (initials) of the individuals responsible for the movement.

B.5 Sample Custody

COC procedures are adopted for samples throughout the field collection, handling, storage, and shipment process. Each sample will be assigned a unique identification label and have a separate entry on a COC record. A COC record should accompany every sample and every shipment to document sample possession from the time of collection through final disposal.

B.5.1 Definition of custody

A sample is defined as being in a person’s custody if one of the following conditions applies:

- The sample is in the person’s actual possession or view.
- The sample was in the person’s possession and then was locked in a secure area with restricted access.
- The person placed it in a container and sealed the container with a custody seal in such a way that it cannot be opened without breaking the seal.

B.5.2 Procedures

The following information typically will be included on COC forms:

- place of collection
- laboratory name and address
- sample receipt information (total number of containers, whether COC seals are intact, whether sample containers are intact, and whether the samples are cold when received)

- signature block with sufficient room for “relinquished by” and “received by” signatures for at least three groups (field sampler, intermediate handler, and laboratory)
- sample information (field sample identifier, date, time, matrix, laboratory sample identifier, and number of containers for that sample identifier)
- name of the sampler
- airbill number of overnight carrier (if applicable)
- disposal information (to track sample from “cradle to grave”)
- block for special instructions
- analysis request information.

The sample identification, date and time of collection, and request for analysis on the sample label should correspond to the entries on the COC form and in associated field log books or sampling forms.

The Data Quality Manager or designated representative is responsible for reviewing the completed COC forms. Any inconsistencies, inaccuracies, or incompleteness in the forms must be brought to the attention of the field staff completing the form. If the problem is significant, corrective action should be taken and documented. Depending on the problem, this may involve informing the laboratory that a sample ID or analysis request needs to be changed, or notifying the FTL that retraining of field staff in COC procedures is indicated. The corrective action and its outcome should be documented.

B.6 Analytical Procedures

Analytical methods will be consistent with, or equivalent to, EPA methods or some other commonly accepted or approved method, as approved by the Data Quality Manager. All laboratory equipment and instruments will be operated, maintained, calibrated, and standardized in accordance with EPA-accepted or manufacturer’s practices.

Laboratory method detection limit (MDL) studies should be conducted for each matrix per analytical method, according to specifications described in 40 CFR Part 136 or other comparable professionally accepted standards. The MDL is a statistically derived, empirical value that may vary.

Laboratory QC samples, which include a method blank, replicate (matrix spike or duplicate) analyses, laboratory control sample, and SRM, will be performed at a target frequency of 1 per 20 samples per matrix per analytical batch. Method blanks should be free of contamination of target analytes at concentrations greater than or equal to the MDL, or associated sample concentrations should be greater than 10 times the method blank values. The matrix spike/matrix spike duplicate and laboratory control sample analyses should meet the specific accuracy and precision goals for each matrix and analytical method.

B.7 Calibration Procedures and Frequency

This section provides information on general calibration guidelines for laboratory and field methods.

B.7.1 Laboratory equipment

All equipment and instruments used for laboratory analyses will be operated and maintained according to the manufacturer's recommendations, as well as by criteria defined in the laboratory's SOPs. Operation, maintenance, and calibration should be performed by personnel properly trained in these procedures. Documentation of all routine and special maintenance and calibration should be recorded in appropriate log books and reference files.

Calibration curve requirements for all analytes and surrogate compounds should be met before sample analysis. Calibration verification standards, which should include the analytes that are expected to be in the samples and the surrogate compounds, should be analyzed at a specified frequency and should be within a percent difference or percent drift criterion.

B.7.2 Field equipment

All equipment and instruments used to collect field measurements will be operated, maintained, and calibrated according to the manufacturer's recommendations, as well as by criteria defined in individual SOPs. Operation, calibration, and maintenance should be performed by personnel properly trained in these procedures. Documentation of all routine and special maintenance and calibration should be recorded in appropriate log books or reference files. Field instruments that may be used include thermometers/temperature probes, scales, pH meters, dissolved oxygen meters, and global positioning system units.

B.8 Data Validation and Reporting

B.8.1 General approach

Data generated by the laboratory and during field measurements may undergo data review and validation by an External QA Reviewer. Laboratory data may be evaluated for compliance with data quality objectives, with functional guidelines for data validation, and with procedural requirements contained in this QAPP.

B.8.2 Data reporting

Laboratories should provide sufficient information to allow for independent validation of the sample identity and integrity, the laboratory measurement system, the resulting quantitative and qualitative raw data, and all information relating to standards and sample preparation.

B.8.3 Data review and validation of chemistry data

Data review is an internal laboratory process in which data are reviewed and evaluated by a laboratory supervisory or QA personnel. Data validation is an independent review process conducted by personnel not associated with data collection and generation activities. External and independent data validation may be performed for selected sample sets as determined by the PM and Data Quality Manager. Each data package chosen for review will be assessed to determine whether the required documentation is of known and documented quality. This includes evaluating whether:

- field COC or project catalog records are present, complete, signed, and dated
- the laboratory data report contains required deliverables to document procedures.

Two levels of data validation may be performed: full or cursory validation. Initial data packages received for each sample matrix may receive full validation. This consists of a review of the entire data package for compliance with documentation and quality control criteria for the following:

- analytical holding times
- data package completeness
- preparation and calibration blank contamination
- initial and continuing calibration verifications
- internal standards
- instrument tuning standards
- analytical accuracy (matrix spike recoveries and laboratory control sample recoveries)

- analytical precision (comparison of replicate sample results)
- reported detection limits and compound quantitation
- review of raw data and other aspects of instrument performance
- review of preparation and analysis bench sheets and run logs.

Cursory validation may be performed on a subset of the data packages at the discretion of the PM and Data Quality Manager. Cursory review includes the comparison of laboratory summarized QC and instrument performance standard results to the required control limits, including:

- analytical holding times
- data package completeness
- preparation and calibration blank contamination
- analytical accuracy (matrix spike recoveries and laboratory control sample recoveries)
- analytical precision (comparison of replicate sample results).

The full or cursory validation will follow documented QC and review procedures as outlined in the guidelines for data validation (EPA, 1998b) and documented in validation and method SOPs. Various qualifiers, comments, or narratives may be applied to data during the validation process. These qualifier codes may be assigned to individual data points to explain deviations from quality control criteria and will not replace qualifiers or footnotes provided by the laboratory. Data validation reports summarizing findings will be submitted to the Data Quality Manager for review and approval.

Laboratory data will be evaluated for compliance with data quality objectives. Data usability, from an analytical standpoint, may be evaluated during the data evaluation. The data users (the PI, PM, AM) will determine the ultimate usability of the data.

B.9 Performance and System Audits

A Data Quality Manager or designee will be responsible for coordinating and implementing any QA audits that may be performed. Checklists may be prepared that reflect the system or components being audited, with references to source of questions or items on the checklist. Records of all audits and corrective actions should be maintained in the project files.

B.9.1 Technical system audits

Technical System Audits (TSAs) are qualitative evaluations of components of field and laboratory measurement systems, including QC procedures, technical personnel, and QA management. TSAs determine if the measurement systems are being used appropriately. TSAs are normally performed before or shortly after measurement systems are operational, and during the program on a regularly scheduled basis. TSAs involve a comparison of the activities described in the study plan and SOPs with those actually scheduled or performed. Coordination and implementation of any TSAs will be the responsibility of the Data Quality Manager or designee.

Analytical data generation (laboratory audit)

Laboratory audits may be performed to determine whether the laboratory is generating data according to all processes and procedures documented in the associated project plans, QAPP, SOPs, and analytical methods. Laboratory audits can be performed by an External QA Reviewer, a Data Quality Manager, or their designee.

Field audits

Field audits may be performed to determine whether field operations and sample collection are being performed according to processes and procedures documented in the study plan, QAPP, and SOPs.

B.9.2 Performance evaluation audits

Performance evaluation audits are quantitative evaluations of the measurement systems of a program. Performance evaluation audits involve testing measurement systems with samples of known composition or behavior to evaluate precision and accuracy, typically through the analysis of standard reference materials. These may be conducted before selecting an analytical laboratory.

B.10 Preventative Maintenance Procedures and Schedules

Preventative maintenance typically is implemented on a scheduled basis to minimize equipment failure and poor performance. In addition to the scheduled calibration procedures described above, the following procedures may be followed.

- Thoroughly clean field equipment before returning to the office. The equipment generally should be stored clean and dry.

- Replaceable components such as pH electrodes and dissolved oxygen membranes should be inspected after and before each use, and replaced as needed to maintain acceptable performance.

- Equipment that is malfunctioning or out of calibration will be removed from operation until repaired or recalibrated.

B.11 Procedures Used to Assess Data Usability

Data usability ultimately is a function of study methods, investigator expertise and competence, and intended uses. QA/QC procedures are designed to help ensure data usability but, in themselves, neither assure data usability nor — if not implemented — indicate that data are not useable or valid. Data validity and usability will ultimately be determined by the PI, PM, and AM using their best professional judgment. Independent data validation, consultations with Data Quality Managers, and review of project-wide databases for data compatibility and consistency can be used to support usability evaluations. The usability and validity of existing and historical data, which were not collected pursuant to the QAPP presented in this assessment plan, will be determined by the AM, PM, PIs, and trustee technical staff using their best professional judgment.

B.12 Corrective Actions

B.12.1 Definition

Corrective actions consist of the procedures and processes necessary to correct and/or document situations where data quality and/or QA procedures fall outside of acceptance criteria or targets. [These criteria/targets may be numeric goals such as those discussed in Section 10.3, or procedural requirements such as those presented throughout the QAPP and other project documents (e.g., SOPs)].

The goal of corrective action is to identify as early as possible a data quality problem and to eliminate or limit its impact on data quality. The corrective action information typically is provided to a Data Quality Manager for use in data assessment and long-term quality management. Corrective action typically involves the following steps:

1. discovering any nonconformance or deviations from data quality objectives or the plan
2. identifying the party with authority to correct the problem
3. planning and scheduling an appropriate corrective action
4. confirming that the corrective action produced the desired result
5. documenting the corrective action.

B.12.2 Discovery of nonconformance

The initial responsibility of identifying nonconformance with procedures and QC criteria lies with the field personnel and bench-level analysts. Performance and system audits are also designed to detect these problems. However, anyone who identifies a problem or potential problem should initiate the corrective action process by, at the least, notifying a PI or Data Quality Manager of his or her concern.

Deviations from QAPP or SOP procedures are sometimes required and appropriate because of field or sample conditions. Such deviations should be noted in field or laboratory logbooks and their effect on data quality evaluated by a PI and Data Quality Manager. Occasionally, procedural changes are made during an investigation because method improvements are identified and implemented. Even though these procedural improvements are not initiated because of nonconformance, they are procedural deviations and typically should be documented.

B.12.3 Planning, scheduling, and implementing corrective action

Appropriate corrective actions for routine problems depend on the situation and may range from documentation of the problem to resampling and reanalysis to the development of new methods. When the corrective action is within the scope of these potential actions, the bench-level analyst or the field staff can identify the appropriate corrective action and implement it. Otherwise, the corrective action should be identified and selected by the PM, the FTL, the Laboratory Manager, or the Data Quality Manager.

B.12.4 Confirmation of the result

While a corrective action is being implemented, additional work dependent on the nonconforming data should not be performed. When the corrective action is complete, the situation should be evaluated to determine if the problem was corrected. If not, new corrective actions should be taken until no further action is warranted, either because the problem is now corrected or because no successful corrective action has been found.

B.12.5 Documentation and reporting

Corrective action documentation may consist of the following reports or forms:

- corrective action forms initiated by project staff that will be collected, evaluated, and filed by the Data Quality Manager

- corrective action log maintained by the Data Quality Manager to track the types of nonconformance problems encountered and to track successful completion of corrective actions

- corrective action plans, if needed, to address major nonconformance issues

- performance and systems audit reports, if such audits are performed

- corrective action narratives included as part of data reports from independent laboratories

- corrective action forms initiated by laboratory staff and summarized in the report narrative.

B.12.6 Laboratory-specific corrective action

The need for corrective action in the analytical laboratory may come from several sources: equipment malfunction, failure of internal QA/QC checks, method blank contamination, or failure of performance or system audits; and/or noncompliance with QA requirements.

When measurement equipment or analytical methods fail QA/QC checks, the problem should immediately be brought to the attention of the appropriate laboratory supervisor in accordance with the laboratory's SOP or Quality Assurance Manual. If failure is due to equipment malfunction, the equipment should be repaired, the precision and accuracy should be reassessed, and the analysis rerun.

All incidents of QA failure and the corrective action tasks should be documented, and reports should be placed in the appropriate project file. Corrective action should also be taken promptly for deficiencies noted during spot checks of raw data. As soon as sufficient time has elapsed for a corrective action to be implemented, evidence of correction of deficiencies should be presented to a Data Quality Manager or PI.

Laboratory corrective actions may include, but are not limited to:

- reanalyzing the samples, if holding time criteria permits and sample volume is available
- resampling and analyzing
- evaluating and amending sampling analytical procedures
- accepting data and acknowledging the level of uncertainty.